Popular Astronomy.

Vol. III. No. 5. JANUARY, 1896. Whole No. 25.

THE CAPE OF GOOD HOPE OBSERVATORY.

HAROLD JACOBY.

FOR POPULAR ASTRONOMY.

In giving an account of a scientific institution like an Observatory, one cannot begin better than by telling about its origin, and how it came into existence. It will be remembered that at the beginning of the present century we possessed no observations made in the southern hemisphere except those of Lacaille. The Cape Colony came into the possession of Great Britain in the year 1815, and it is a remarkable fact that so soon afterwards as October, 1820, a memorial from the Lords Commissioners of the Admiralty was read at the Court at Carlton House, "present the King's Most Excellent Majesty in Council."

"The Board of Longitude having resolved that it would be highly conducive to the improvement of practical astronomy and navigation that a permanent Observatory should be established at the Cape of Good Hope, His Majesty, having taken the said memorial into consideration, was pleased, by and with the advice of his Privy Council, to approve of what was therein proposed."

The matter was pushed on with great vigor. In October of the same year, the Rev. Fearon Fallows was appointed His Majesty's Astronomer at the Cape of Good Hope, and he sailed from England on the 4th of May, 1821. It took him just one hundred days to get to Capetown, and after his arrival a series of most annoying delays followed. The plans of the Observatory buildings, which he had discussed before leaving home, did not actually reach the Cape, with the necessary authority to carry them into execution, till December 1824. In the meantime a site had been selected on the top of a small hill called Snake Hill, for good and very obvious reasons. Here the Observatory was built, and it was built solidly enough to last some centuries. The original building is still the main building of the Observatory, and from its roof the shipping in Table Bay can be seen. In the museum of the Observatory is still preserved an old pistol with which Fallows used to send a noon-signal to the ships for purposes of navigation. But bad luck pursued the first Director of the Observa-

tory. Assistant after assistant failed him, and his own constitution finally broke down under the excessive strain he put upon it in trying to accomplish good work under very adverse circumstances. He died at the early age of 43 years, and his body rests in the Observatory grounds not far from the building he erected. Fallows' grave, about which the jackals used to howl, and where poisonous snakes had their home, is now surrounded by a fair garden of flowers, planted and tended under the care of the present director's wife.

Thomas Henderson, who succeeded Fallows, remained at the Cape one year only, and resigned in 1833. His health could not stand the disagreeable features of life at the Cape Observatory at that time. He left a specification of the alterations necessary "to render the Observatory a fit place of habitation for persons accustomed to respectable life in England." Henderson's principal achievement was to produce, for the first time, reliable evidence of parallax in a fixed star.

Henderson was succeeded by Maclear, who held the office of astronomer from 1834 to 1870. It was during his directorate that Sir John Herschel made his famous series of observations at the Cape. These were not made at the Observatory, however, but at Sir John's residence a short distance away.

In the face of difficulties too numerous to mention, and of such a character that only the fact that he surmounted them prevents their being called insurmountable, Maclear effected his great work of verifying and extending Lacaille's arc of the meridian. The work was published in two large quarto volumes, now very rare, and is of the very highest importance in geodesy. For this work Maclear received the medal of the royal Society of London, and the Lalande medal of the Institut of France.

In addition to the above, Maclear made a very extensive series of observations of fixed stars with the meridian circle and also a quantity of parallax observations. He possessed great capacity for very hard work, and he utilized it to the utmost for the benefit of science. The consideration in which he was held at the Cape is evidenced by the fact that the House of Assembly at Capetown passed elaborate resolutions at his death, although, as a crown officer, he had not any special claims on the Colony, except for services performed outside of his official duties. Like Fallows, Maclear was buried in the grounds of the Observatory.

The next astronomer was Mr. E. J. Stone, now Director of the Radcliffe Observatory at Oxford. Stone carried out the reduction and publication of a large mass of observations left unre-

duced by Maclear, and also published the well-known catalogue of stars which bears his name.

Having thus briefly called attention to the most important facts in the history of the Cape Observatory, we now come to the description of the Observatory as it is, and to the directorate of the present astronomer. Dr. Gill came to the Observatory in 1879, and he immediately set about the extension of its usefulness in a very energetic way. He had been for many years a student of the great and important problem of the Solar Parallax, and the solution of this problem with an accuracy hitherto unattained has been made one of the principal objects of work at the Cape Observatory. Stellar parallax too has been one of Gill's principal subjects of research. For both problems the Repsold heliometer has been the instrument used. One of these instruments, at the time of its construction the most powerful and complete of its kind, was added to the instrumental equipment of the Observatory some years ago. Previous to the arrival of the new instrument, Dr. Gill devoted himself to measurements of stellar parallax with a small heliometer which belonged to himself. In this work he was assisted by Dr. Elkin, now astronomer at Yale college. The results obtained are of the highest precision and greatest value.

In the Solar Parallax work also, Dr. Elkin has co-operated with Dr. Gill. But in this instance Dr. Elkin's observations were made in New Haven instead of the Cape Observatory. Yale College possesses a heliometer very similar to the one at the Cape, and the plan of the work included a series of simultaneous observations at both stations. It is not possible here to enter into a detailed description of the methods employed in this most important piece of work. But the general idea is this:

One of the minor planets was selected for observation, and its position with respect to certain small stars near it determined simultaneously at the two stations by very careful observations with the heliometer. It is clear that the apparent position of the planet as seen from the two stations will vary slightly on account of their being situated on opposite sides of the earth. In other words, we have a means of measuring the distance from the Earth to the planet, using the straight line joining the Yale and Cape observatories as a base-line. The distance of the planet once known, it is easy to compute the distance of the Sun. For our knowledge of the orbits of the minor planets used in this research is such that we can say we know with almost absolute precision the ratio of the distances of the planet and Sun from the Earth. The value of

this great and laborious work will be better appreciated by astronomers in general after the final publication of the methods and results shall have taken place. They will fill three large quarto volumes and will undoubtedly take their place as one of the astronomical classics. Newcomb sums the matter up well when he says: "So far as practical astronomy has yet developed, the best method of directly measuring planetary parallax, and therefore the only one to be considered is that of Gill."

It is impossible here to do more than refer to the other important work of the Cape Observatory in the briefest possible way. It was here that the great photographic "Durchmusterung" of the southern heavens was undertaken and finished. The plates were measured by Professor Kapteyn at Gröningen in Holland, and have furnished us with the approximate positions of all the stars in the southern hemisphere, down to about the tenth magnitude. The catalogue, which is now in the press, will fill three quarto volumes. It will be arranged like Argelander's "Durchmusterung," and the positions are given by the photographic observations with a precision which is not inferior to that attained by Lalande. The number of stars in the catalogue actually approximates to half a million.

The other important piece of work now in progress at the Cape is the Astro-photographic Chart of the Heavens. Of course the Cape Observatory is only one of a number of Observatories taking part in this work. But to the Cape Observatory and to its present director belong the credit of having brought about the beginning of this great enterprise, and it is being pushed there with characteristic energy. In addition to all these matters, the regular routine of meridian observation and reduction goes on, and the last year has seen the publication of the Cape five-year catalogue, which is in many respects the most interesting of recent star catalogues.

Here in the shortest possible form, is an account of the Cape Observatory and its work in the past and present time. What are the lessons to be learned from it by the American astronomer? To me they seem to be these:—To pass his life in a manner most worthy of that Science which has well been called the Queen of the Sciences, let the astronomer devote himself to those great cosmic problems whose very contemplation elevates and expands the mind, even though their solution by his own hand and brain shall be estopped by Death. Let him not think that mere looking at a planet, and describing what is seen with a powerful telescope, and an equally powerful imagination, would ever have given

PLATE VIII.

The Cape of Good Hope Observatory, Cape Colony, S. Africa.

The Main Building.

[From a Photograph by C. Ray Woods.]

Road to Observatory, Dent's Peak in Background, and Behind the Peak the Flat Top of Table Mountain is Visible.

[From a Photograph by C. Ray Woods.]

her proud title to the Science of Astronomy. To the man who has unveiled to us the secret laws of Nature, unseen by the very eyes that scanned the face of the sky, undetected by the hands that measured the positions of the heavenly bodies, to him is the merit, let him bear the palm.

OBSERVATORY OF COLUMBIA COLLEGE, N. Y.

TYCHO BRAHE.

CAROLINE E. FURNESS.

FOR POPULAR ASTRONOMY.

There are many illustrious names which adorn the records of astronomical progress. Of the men who bore them, some have been pioneers, and by their achievements have carried astronomical science forward a distinct step, while others, more distinguished perhaps, have pursued with profound study the investigations made possible by the work of their predecessors. While we honor these later men for their splendid talents, we must remember that a firm basis for their work was already laid. They were born in favorable circumstances, were encouraged and stimulated by the men of genius about them, and the spirit of inquiry was abroad in their midst. Yet we must not, from comparison with these great men, stint the praise we give to those earlier astronomers who laid the foundations upon which the superstructure of theoretical astronomy has been built.

The spirit of inquiry which glowed so brightly in the Hellenic nation died down, and burned with but a feeble flame during the dark ages. Kept alive by the Saracens, it revived again when Europe awoke from its long sleep. The fetish-like worship of Aristotle fostered by the Romish church interfered with the progress of all science, but with the Reformation, the discovery of America, and the downfall of Constantinople, came a rebellion against the old Greek, and scientists began to think for themselves. After the time of Ptolemy there was a long interval in which no marked progress was made. Astronomers were content to work over what had been done by the Greeks and to give much of their time and knowledge to the more profitable subject, astrology. Then came in quick succession Copernicus, Tycho Brahe, Kepler, Galileo, and Newton, and the foundations of mathematical astronomy were securely laid. Let us briefly review the state of astronomical knowledge in the time of Tycho that we may better understand his great contribution to science.

The Greeks were familiar with star cataloguing, predicting of eclipses, with precession, and with certain variations in the uniform motion of the Sun, Moon and planets. From Ptolemy we have the complicated system of the world consisting of eight spheres into which are distributed all the heavenly bodies. The Earth holds the central place and all the planets revolve about it in eccentric circles and epicycles. To believe that a heavenly body could move in any but a circular path was heretical and irreligious, since only circular motion could be perfect. To the early observers with their rough instruments, his system represented fairly well the motions of the planetary bodies. After a lapse of fourteen hundred years, however, the observed positions no longer agreed with those computed on Ptolemy's theory. Several able mathematicians endeavored to improve upon the tables already published, notably Regiomontanus, who constructed ephemerides which were much better than any known before, but even these were at fault, and it became evident that the theory was inadequate to explain the facts.

At this juncture Copernicus developed his theory of a heliocentric system and presented a new explanation of planetary motion. This was a tremendous stride in advance, but like his predecessors Copernicus introduced eccentric circles and epicycles to account for irregularities, and while his theory more nearly represented the real arrangement of the solar system and was much less complicated than Ptolemy's, it was still somewhat cumbersome and only roughly approximated the truth. He had no more testimony gathered from actual observation, upon which to support his new ideas than had the followers of Ptolemy, and while many scientists believed in his system as simpler and more reasonable, it did not recommend itself to all. When Tycho Brahe came to maturity, matters were at a standstill. No one was satisfied with the existing state of knowledge, yet no one seemed to realize the only method of improving it. To him, then, we owe the beginning of our present development of astronomical science. He was the first to recognize the fact that we must dispense with the inadequate theories of the ancient astronomers, or hold them only tentatively, and base all future hypotheses on actual observations, which must be made with the greatest accuracy possible While he did not add greatly to the sum of theoretical knowledge, he placed all succeeding work upon the solid foundation of actual fact. From his time, astronomy became an exact science, and no theory has received much consideration unless supported by an abundance of undisputed evidence.

Tycho Brahe was born of a noble family, in 1546, in the southern part of the Scandinavian penninsula, which at the time formed part of the Danish kingdom. While he was a student in Copenhagen, a partial eclipse of the Sun occurred, and his interest was so aroused by the sight, and it seemed so wonderful to him that men could foretell such a marvelous event, that he became absorbed in the study of astronomy. As this did not seem suitable to a young man of his station and prospects, he was sent to a German University, under tutorage, with the hope that he might be diverted to a more dignified pursuit, but in vain. He began a surreptitious study of all the planetary tables he could procure, and at once found them largely in error. Even at that early age, he perceived that upon observation and observation alone should all theories be founded. His first recorded observation is of the conjunction of Jupiter and Saturn; which he observed with a crude instrument resembling a pair of compasses. He found one table to be a whole month wrong and another several days in error. From this time he began to note the positions of the planets, sometimes by measuring their distances from certain stars, and sometimes by geometrical figures in the sky. Gradually he added other simple instruments to his equipment and began to observe more openly. He visited Denmark at this time, and while his family were still opposed to his scientific studies, the perseverance with which he carried on his work interested other people, and finally the king promised him support. He returned to Germany, now his own master, and with the limited means at his disposal set up new instruments and made observations, though somewhat irregularly. He had not, as yet, devoted his life to practical astronomy, though he realized the necessity of such work, but his wavering ambition was suddenly fixed. One night looking up into a clear sky, he saw a brilliant star in Cassiopeia where none had been before. Scarcely believing his senses, he called upon those with him to verify what he had seen. At once he began a series of observations, determined carefully the position of the star, found that it did not move, and discovered that it had no parallax, thus placing it among the stars in the eighth sphere and not within the Moon's orbit where all new celestial objects had previously been put. His observations attracted great attention and gained for him much distinction, so that the king, Frederick II, of Denmark, wishing to retain so learned and promising a man in his kingdom, offered to confer upon him certain revenues if he would reman in his native country. This Tycho gladly agreed to do, and at once settled himself on the tiny island of

Hveen which was deeded to him during his lifetime, with certain other resources.

On this Island he built a house and observatory buildings, and appropriately called the place Uraniborg. Here he set up his instruments, and here, many young men, attracted by his fame, came to act as his assistants. For twenty years he directed their observations, improving from time to time the accuracy of his instruments, and collecting, ultimately, a large mass of valuable material. After the death of his patron, Tycho lost favor at court, partly through personal enemies and partly on account of his own natural arrogance of temper, which led him to offend the young king. Support was withdrawn from him, and feeling unable to continue such extensive work unaided, he left Denmark for Germany, and after some wanderings was invited to Prague to the court of the Emperor Rudolph. Here he tried to establish a second Uraniborg, but the ruler of the great Roman Empire had not at his disposal so much money as the king of little Denmark, so that Tycho could not carry out his plans. At Prague, Kepler, then a rising young mathematician, became his assistant and after Tycho's death, which occurred at the early age of fifty-two, he preserved his records and from them derived the elliptic motion of the planets. The name of this young assistant is greater than that of his master. Kepler's laws are fundamental: they are the groundwork of modern mathematical astronomy; but Kepler found those laws in Tycho Brahe's observations and without that mass of material to work upon, he might have labored in vain.

Tycho did not accept the Copernican system but evolved one of his own in which he makes the planets revolve about the Sun, but the Sun carries them with itself about the Earth. Part of his observations he reduced himself, publishing among other things a book on the new star of 1572, one on comets, and one on the lunar theory, and an important star catalogue. He had planned several other valuable works, but his early death cut short his projects. He was the first to perceive the importance of applying refraction to observations. He improved the values of the Sun's and Moon's perigee, he discovered two variations in the Moon's longitude in addition to those already known, and one in latitude. In short he improved many values which depended on accurate observation for their determination.

Another great advance which he made was in the method of observing and in the instruments used. Similar instruments to his had been invented before, but he made them larger and more

accurate. His equipment at Uraniborg was much more complete than the apparatus he set up after he left Denmark, since he had more room at his disposal and more money to build with, in his former station. One of his best pieces was a large mural quadrant fastened to the wall of one of the rooms at Uraniborg. It consisted of a brass arc seven feet in radius, and five inches broad, divided into degrees. There were two sliding sights on the arc and a hole in the south wall at the center of the circle through which the observer sighted. This was used largely for obtaining meridian altitudes of stars and was in constant use. He also had a number of smaller movable quadrants, which he used to measure the distances of stars, by placing the eye at the center. For the same purpose he had a large portable sextant which could be mounted on a stand out of doors, which required two observers to operate it. It resembles the modern sextant in part only. It had three sights, one at the end of the movable radius, one at the end of the fixed radius, and the third at their intersection. The two observers sighted two stars, one through the fixed opening and the central cylinder, the second through the movable and the central opening. This also was very useful and accurate. Another sextant was employed in a manner similar to the quadrants, by placing the eye at the center and sighting the two objects simultaneously. There was also a fixed sextant for measuring the meridian altitudes of planets, which never exceeded 60° at Uraniborg. In his earlier observations he used a cross staff which though simple in construction is not very accurate, and which he afterward discarded as he acquired means for making better instruments. It consisted of a movable cross bar sliding on a longer bar, both of which were divided. A sight was placed at one end of the long bar for an eyepiece, a second on the movable bar at the middle, and the third moved to and fro on the cross bar. The sights thus formed a right angled triangle, and with the assistance of a table of tangents, the angle between two stars could be determined. Another instrument, which was employed for observing declinations directly, was the armilla. It consisted of two large steel circles fastened together and so mounted that one represented the equator, the other the meridian. To these was pivoted a declination circle with movable sights, by means of which observations of declination were made. There were other devices which simplified the work or made the results more accurate. In certain cases instead of computing laboriously the parts of a spherical triangle, he determined them graphically by means of a large globe. He improved the sights

so that stars could be located more accurately and those of different magnitudes equally well. The divisions of the scale on his larger instruments were made on two concentric circles. By means of transversals, which were diagonal rows of dots connecting a division on the inner circle with the succeeding one on the outer circle, he was able to read to 1′ of arc.

At the present time, when every effort tends toward refinement of instruments, and toward the elimination of all possible sources of error, we may not realize how much that is really fundamental in astronomy was done without a telescope. Students, especially need to be reminded that the telescope is not indispensible to accurate knowledge, and that many useful results can be obtained without it. For beginners in astronimical study simple models in wood can be made, of the cross-staff, quadrant or sextant, and can be used advantageously to train the eye in accurate seeing, as well as to illustrate early forms of instruments.

VASSAR COLLEGE OBSERVATORY.

THE GROWTH AND MAGNITUDE OF THE SIDEREAL HEAVENS.*

W. H. LAMASTER.

FOR POPULAR ASTRONOMY.

Let us, in our imagination, place ourselves at some commanding point of vision in the universe, and with the power of taking into view the whole of the sidereal heavens, and what might we behold? The only answer would be, millions of revolving worlds —flaming suns, planets and satellites. In the movements of these heavenly bodies there would be presented to us a celestial panorama both grand and imposing; and while we may think that we live on a world of great magnitude, we ought to know that there are others many millions of times greater. Indeed, we should know that our earth is so very small that to the inhabitants of some other planets, even in our own solar system, it is but a mere blank in eternal space. It is to be at least hoped that the astronomers of Uranus and Neptune (if such there be) have telescopes of sufficient power to take within their field of view, our world.

People once regarded our earth as the center of the universe, and even religiously believed that it was flat and had four corners. As late as the 15th century, the most reverent and learned Prelates of the Great Council of Salamanca "ridiculed, with great success, a project involving such an absurdity as the existence of

* See general note on this article elsewhere.

the antipodes. where men walked with their heels above their heads, where the trees grew downward, where the snow and rain fell upward from a nether heaven," and in the eyes of that most holy Council, "To maintain that the earth was inhabited beyond the tropics savored of blasphemy." Science, though, has at last about opened men's and women's eyes to the character of not only our own world, but that of the Sun and the Moon and the stars also.

The Chaldeans are supposed to have been the first astronomers. When it was that the Chaldeans began the study of Astronomy is not definitely known, and yet if Porphyrius is to be accepted as authority, they sent some of their observations on the stars to Greece about two thousand years before the time of Alexander the Great. "While it is certain," says Ideler, "that the Chaldeans knew the mean motions of the Moon with an exactness which induced the Greek astronomers to employ their calculations for the foundations of lunar theory." And Humboldt adds, that "the planetary observations to which they were led by their ancient love of Astrology appear also to have been used for the true construction of astronomical tables."

Astronomical observations were also made by the Chinese before our era. Humboldt tells us that "the most ancient astronomical observations which have come down to us with accurate numerical data, reach back to the year 1104 before Christ, and testify to the extreme antiquity of Chinese civilization." It is also conceded that to Chinese astronomers, the obliquity of the ecliptic was well understood hundreds of years before Christ, and that even the meridian shadows had been measured with very great accuracy by Chinese astronomers in two solstices upon an eight foot Gnomon. While it might be well to also note that from the middle of the third century of our era to about the close of the fourteenth, it was "the practice of European astronomers to calculate the time of the coming and going of comets from ancient Chinese observations."

Pythagoras of Greece, who flourished 500 years before the Christian Era, taught Astronomy at the famous school at Crotona, and is said to have exhibited a more profound knowledge of the Celestial heavens than any other ancient astronomer. However, his views seem to have never been very generally accepted until they were revised by Copernicus, Galileo and Kepler. The most renowned of all the ancient schools of Astronomy was that at Alexandria, in Egypt. This school was founded and supported by the Ptolemies about three hundred years before Christ, and its

most able and profound astronomer was Hipparcus, who lived B. C. 150 and was distinguished for the great accuracy of his star measurements and calculations. But whatever may be said in favor of the schools of antiquity or the erudition of the ancient astronomers, it is to Copernicus of Prussia, Tycho Brahe of Denmark, Kepler of Germany, and Galileo of Italy that the world is now indebted for the laying of the foundation of its present system of astronomy.

The most celebrated systems of astronomy have been the Ptolemic, the Tychonic and the Copernican. The first two were founded upon the idea that the Earth was the center of our solar system, while that of the latter was based upon the hypothesis that the planets, including the Earth, revolve around the Sun. However strange it may appear, the eastern world at least, had no other knowledge of our solar system worth mentioning for two thousand years than was taught by the Alexandrian school, as found in the Almagest, or until about the sixteenth century of our era. We need not wonder though at the very limited knowledge of the ancient astronomers, or even at that of some of the modern ones, concerning the true motions of the heavenly bodies, when we consider that the telescope, with its wonderful revealing powers, was unknown until A. D. 1608.

With the introduction of the telescope came a new revelation to mankind of the heavens. Instead of a few thousand stars that are to be seen with the naked eye, many millions have been discovered revolving with the most perfect order in the great and boundless ocean of space. And thus the minds of men are being led from "simple premises" to those "exalted heights" whence they may study to perfection those myriads of worlds radiating as they do, with the glittering brightness of their own great splendor and glory.

Astronomy, like every other science, is subject to the most wonderful of revolutions. What may be to-day a supposed fixed doctrine of the Cosmos, may be overturned and abandoned to-morrow. Progress is always the watchword with the "star-gazer." His march is ever onward and upward in every pathway which may lead into new celestial fields. While in every celestial garden there are always to be seen looming up before his vision new ideas and new theories, and with them his mind is ever ready to grapple.

It will not be denied that all the heavenly bodies have grown from small beginnings to their present magnitudes. Hence, whatever may be the size of any revolving world, we must con-

clude that it began with the atom. So, then, to start with the atom as the nucleus, or central body of attraction to which all its other atoms are to unite in the process of world making, we will find that upon the union of the first two atoms, they possess a force of the first power, and when four atoms become united a force of the second power, and so on in the same diametrical ratio until in an asteroid, planet or sun, there are to be found many millions of powers, and I would add that with each union of atoms, there is also to be found in a like ratio an addition of heat, and as the magnitude of any celestial body increases, its heat will increase.

Every celestial body though must attain a certain magnitude before its own heat is to be seen manifesting itself to any very great degree, and then, it must begin, first at the center of every such orb—its center becoming heated by reason of the action of what is called a centripetal static force. As every celestial body continues to grow by reason of the meteoric substances falling to its surface, its interior continues to heat until its center is at last found to be in a molten condition, and as this heat continues to increase and to extend toward the surface, it must of necessity cause a diminishing of the thickness of the cold crust of every celestial sphere. First then, are to be seen volcanic eruptions, and at last instead of planets like our own, Jupiter or Mars,—blazing suns.

In every process of world making the atoms are first united by attraction and afterwards they are found to arrange themselves into crystals by polarity, while their further agglomeration with whatever may be their polar adjustments "constitutes nebula, either sporadic or in collective groups of every conceivable form and size."

In every world still in embryo, if there is any heat at all, it can only be a latent one. There never can be manifested an active heat where there is neither pressure nor friction, and when it does appear, it will always be found greatest, as Professor Spencer tells us, "where the atoms are subject to the greatest pressure." Therefore in the star dust and vaporous nebula from which worlds are first formed, there can be no active heat, but latent only. Hence, we may well argue that neither our Earth nor any celestial body could have been in a once nebulous state, and at the same time a molten mass.

Motion being a primary condition of matter, and heat a secondary one, we can therefore, only conclude that whatever may be the developments to be seen to take place in celestial bodies,

are to begin with the total darkness and frigidity of such bodies. To argue, as some do, that our Earth was once a molten mass and is now cooling instead of heating, is to deny the very laws themselves, which underlie the whole primary condition of matter.

The great density of the several satellites which accompany planets in our solar system is also a very strong proof in favor of the truth of the theory that all the revolving spheres in the heavens are increasing in heat rather than diminishing. Our own Moon is almost as dense as our Earth, and instead of its being, as Sir John Herschell supposed, "an orb very much heated possibly to a degree much exceeding that of boiling water," it is now known to be about sixteen times colder than the Earth: while Jupiter, that mighty planet, even at its surface, is found to be almost incandescent, and less dense than the Earth.

That our own solar system has now but one central sun, is no reason whatever that it did not at one time have two. The very fact of there being discovered what are known as double stars, (suns), is a very good proof that every other solar system in the universe is not always like our own as regards the number of their suns—in an uni-solar condition; and there can be little, if any, doubt that the coal measures now to be found deposited in our Earth, were made during a period when our solar system had two central suns, and it is reasonable to suppose that a secondary sun in our solar system, and one too, if it should have revolved in close proximity to our Earth, have sooner or later converted the Earth's vegetation into coal.

We need not go beyond our own solar system to find worlds whose magnitudes compared to the one we inhabit are so much greater than it, that it is made to dwindle into one of almost insignificance. Even our own Sun, which is more than one million times larger than the Earth, considered as a star, is found to be one of the smallest in the heavens. And what, then, must be our conclusions as to the magnitudes of some other revolving worlds? Who can grasp, even with the imagination, the immensity of such spheres? Well might Dr. Thomas Dick have exclaimed, as he did, that "The mind is bewildered, confounded and utterly overwhelmed when it attempts to grasp the magnitude of the universe, or to form an idea of the Omnipotent energy which brought it into existence."

Sir William Herschell was able to perceive no less than 50,000 stars, (flaming suns) in one small point in the Milky Way, which lies near the constellation Orion, pass before the field of his tele-

scope in one hour. And what then, must be the number of such orbs in the universe? It has been reckoned that there are 100,000,000 stars within range of our telescopes, and yet, who would dare say but that number is only a very small one as compared to that which comprises the whole Cosmos? When we consider also that between each of these celestial bodies there is an intervening space of many millions of miles, and that between even our own Sun and the nearest fixed star, there is an interval of more than twenty billions of miles, what must be our idea of the interval between our Sun and the farthest one?

Thus we may see in the great garden of the universe, celestial bodies undergoing their multiple changes of development from the smaller to the larger, and from the lower to the higher. First the asteroid, cold and frigid, then the growing planet, and lastly, the mighty revolving sun, with its glowing heat illuminating with its seven-hued rays of celestial splendor, the starry regions of eter. measureless space.

Knowing then, that every fixed star is a sun, and reasoning by analogy, as we must, we may very well conclude that as our sun is the center of our solar system, every other sun or fixed star must also be the center of a like solar system; and there being also many millions of such other suns or fixed stars in the universe, there must also be many millions of like systems, and yet, who can number them or measure their immensities?

It has been estimated that a cannon ball moving with a velocity of 500 miles an hour, and leaving our earth at a certain time and traveling in the direction of the nearest fixed star, would not reach it is less than 4,500,000 years; and yet, there are stars in the heavens and visible through telescopes, that would require a a cannon ball moving with the same velocity at least 500,000,000 years to reach them. It was said by the elder Herschell that it would require light travelling at the rate of 185,000 miles a sec. ond, two millions of years to come to the earth from the remot. est luminous vapors within reach of his 40-foot telescope, and yet, whatever may have been the efforts of astronomers to bring the starry heavens as a whole into view, even with the most powerful reflectors, have so far proved to be futile. Hence, to the minds of men, the universe must seem forever to be and to remain immeasurable, incalculable and incomprehensible. And while we may be able to weigh and measure suns and systems within range of our telescopes, there are others so far away and so far beyond our powers of vision, and our power of calculation, that even our present supposed great knowledge of the siderial heavens would dwindle into the thinest of mental vapories.

Within this mighty domain then—this great universe of celestial grandeur—are to be seen these myriads of revolving worlds and systems, and yet, of the forces that are in operation throughout so vast a sidereal empire, operating in every conceivable direction, who can calculate them, or comprehend them? And are these countless orbs, we would also inquire, to be only thought of as sterile and desolate worlds, to be reckoned only as so many celestial points in the heavens to delight the eyes of men on our diminutive sphere? Surely not. Let us then, in our magnanimity, rise above the compass of our human selfishness and allow our minds to be inspired with the thought that there are other worlds than ours in the starry vaults of heaven, which are the abode of even more sentient beings than ourselves.

INDIANAPOLIS, Ind.

THE MEAN DENSITY OF THE EARTH.

J. H. POYNTING.*

FOR POPULAR ASTRONOMY.

This essay, which contains an account of Professor Poynting's well-known investigation of the mean density of the Earth, though the last Adams prize essay, is the first to which that prize has been awarded for experimental work. We hope that it is the first of a long series of essays in which the candidates will attack the questions proposed by experiment as well as by mathematical analysis. We can hardly expect, however, that the level reached by the magnificent experimental work of Professor Poynting will always be maintained.

The essay consists of two parts, the first containing an account of previous determinations of the mean density, the second an account of Professor Poynting's own determination by means of the ordinary balance.

The first part begins with an account of the astronomical or geodetical methods, in which the attraction of a mountain was compared with that of the Earth, as in the experiments of Bouguer in Peru, of Maskelyne and Hutton on Schehallien, of James and Clark on Andrews Seat, of Carlini on Mount Cenis, and of Mendenhall on Fujiyama; or with that of the slab of matter above the surface of a mine as in Airy's Harton Pit experiments, and von Sternech's experiments in Pribram and Freiberg.

* An essay to which the Adams Prize was adjudged in 1893 in the University of Cambridge.

The beautiful method employed by von Sterneck in his pendulum experiments ought to be more widely known in England. The object of the astronomical method has undergone a curious reversal. It was originally to deduce the mass of the Earth from a supposed knowledge of the distribution of matter in the locality of the experiment, whereas now it is rather to find the distribution of matter in this locality, assuming the mass of the Earth to be known.

The other methods are laboratory methods, and depend upon the measurement of the attraction between known masses. Professor Poynting points out a very interesting under-estimate of this attraction made by Newton. In the Principia, Newton estimated that two spheres of the density of the Earth, each a foot in diameter, would, if separated by quarter of an inch and left to their own attractions, take nearly a month to come into contact. Professor Poynting shows that there is a mistake in the arithmetic, and that in reality the spheres would come into contact in between five and six minutes.

It is now very nearly a century since the first measurements of the attraction between two masses in a laboratory were published by Cavendish ("Experiments to Determine the Density of the Earth," *Phil. Trans.*, 1798), who used the torsion balance. Since then this method has been used by Reich, Baily, Cornu and Baille, and Boys; while the ordinary balance has been used by von Jolly, Professor Poynting himself, and by König, Richarz and Krigar Menzel, working in collaboration, while the method of the pendulum balance has been used by Wilsing. The labor expended over these investigations may be estimated from the fact that, to take only two modern instances, Professor Poynting's experiments extended over twelve years, while those of Cornu and Baille were commenced in 1870, and are not yet completed. The essay contains a clear and critical account of the preceding experiments. The result of the criticism is to raise, if possible, Cavendish's fame as an experimenter. Of Baily's laborious research, Professor Poynting says: "The critical examination it has received in later years has entirely destroyed any confidence in the result. It remains, however, as a most remarkable and useful example of the danger of substituting multiplication of observations for consistency." The contrast between the amount of work which has been published on the numerical magnitude of the attraction, with that which has appeared on the effects, if any, which modifications of the surroundings exert on this attraction is very remarkable. Newton's hollow pendulum

experiments, repeated with greater accuracy by Bessel, seem to be almost the only investigations which have been published on what may be called the physical properties of gravitational attraction. As far as we know, the attraction between two given masses depends merely upon their geometrical configuration; it is independent of the medium between them, of the physical state of the masses, whether they are solid, liquid or gaseous, amorphous or crystalline; it does not depend upon the temperature of the masses. Indirect evidence, often derived from the Cavendish experiments, shows that the preceding statements must at least be very approximately true. Again, chemical analysis is founded on the hypothesis that the weight of an atom of a chemical element is unaltered whatever chemical combinations it may form, or whatever the temperature to which it may be raised. It is, however, often difficult to tell the degree of approximation to the truth of the preceding statements which is indicated by such indirect evidence, and a direct experimental investigation to determine an inferior limit to the accuracy of some of the preceding statements would not be superfluous. Take the case, for example, of the statement that the weight of an atom cannot be altered by chemical combination: it would be for the advantage of science if this were proved with the utmost possible accuracy attainable by present methods for some definite chemical combinations. The question is of interest in connection with the view that the atoms of elements are aggregations of atoms of some primordial substance not very much lighter than hydrogen. The values of the atomic weights of the elements is inconsistent with this view if each atom of the primordial element retains its weight unaltered in the complex atom. If, however, it suffers a slight change of weight, then we might expect to find traces, though perhaps faint ones, of such a change in ordinary chemical combinations.

Another question which has excited some interest is a possible connection between the magnitude of gravitational attraction and temperature. Professor Hicks has pointed out that Baily's results gave a value for the mean density of the Earth which uniformly diminished as the temperature increased, indicating, if the effect is a real one, that the attraction between two masses increases with the temperature, and von Sterneck, in his experiments at Freiberg, found a remarkable relation between the temperature and the value of gravity. Professor Poynting discusses these and other results, and comes to the conclusion that they are to be explained by other causes, and do not afford any evi-

dence at all that the attraction between bodies varies with the temperature. The point is one which has a direct bearing on Professor Poynting's own experiments, as the final value for the mean density is got by taking the mean of two sets of experiments, and as the temperature in the two sets differed by about 3°.5 C., an uncorrected temperature effect would affect the result.

We are very glad to find from this essay that Professor Poynting is engaged on an investigation as to whether the attraction between two crystals depends on the relative position of their axes.

The second part of the essay consists of Professor Poynting's paper "On a Determination of the Mean Density of the Earth," published in the *Phil. Trans.*, for 1891. This, in addition to the actual determination of the mean density, is almost a treatise on the method of using a balance so as to get great sensitiveness. The work is a model of patient care and skill, as well as of clearness of exposition, and we feel as we read it that the utmost has been made out of the apparatus and the method. Professor Poynting is of opinion that it is only air-currents which prevent the balance being used with an accuracy far beyond anything hitherto approached; the ordinary balance is more sensitive than the torsion balance to air-currents, since these produce the greatest disturbance in the vertical direction, which is the direction of displacement in the ordinary balance. Professor Boys has shown that to minimize the effect of air-currents the size of the apparatus ought to be reduced as much as possible. Professor Poynting says that if he were designing his apparatus again, instead of using, as he did, an exceptionally large balance, he would go to the opposite extreme and use a very small one.

Of all the methods hitherto used to determine the mean density of the Earth, the arrangement used by Professor Boys seems to be the one capable of the greatest accuracy. There are, however, certain points about the method of the common balance, such as the simplicity of the most important measurements, and the absence of the necessity to determine a time of swing with great accuracy, which make it worthy of such a work as Professor Poynting has devoted to it.

The mean density of the Earth found by Professor Poynting is 5.49. Professor Boys' result is 5.53.—*Nature*, October 4, 1894.

CELESTIAL PHENOMENA FOR THE YEAR 1896.

H. C. WILSON.

For Popular Astronomy.

In looking through the Almanac for 1896 one will notice among the phenomena predicted for the year none which are of predominant interest. The planets pursue their prescribed paths through the heavens without notable event, the Moon circles in an orderly manner about the Earth, interfering with the light of the Sun and stars and piercing the shadow of the Earth only the average number of times. There are no transits of Mercury or Venus, and only one eclipse which an astronomer would go any distance to see. Yet the amateur as well as the professional astronomer will find enough to interest him in the common events which, recurring so often as to excite little remark, yet recur with such wonderful precision that they can be predicted years in advance. Then too there is always the uncertainty of the unforeseen, to give zest to astronomical study; new comets, new planetoids, new stars, new variables, new binaries to be discovered and new theories to be developed.

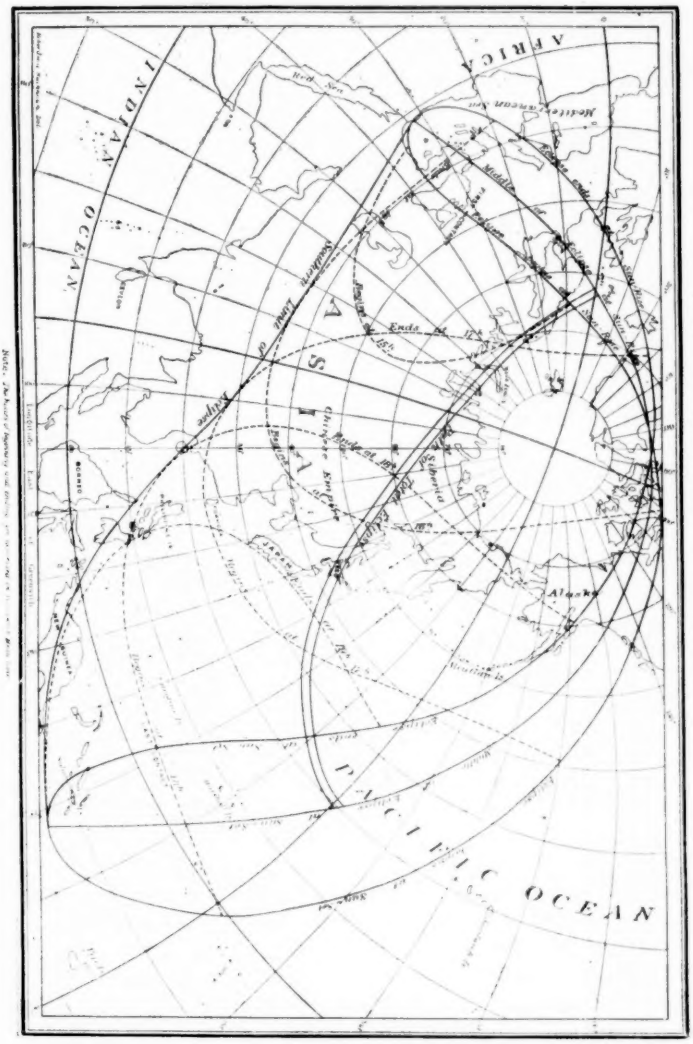
Eclipses.

There are to be four eclipses during the year 1896, two of the Sun and two of the Moon. The first is on *annular eclipse of the Sun*, February 13, which will be invisible in the United States. The central line of the annulus passes across the Antarctic Circle, thence north and eastward toward the southern coast of Africa, touching known land nowhere. It will be visible as a partial eclipse along the southeast coast of South America and the southern part of Africa.

The second eclipse is *a partial eclipse of the Moon*, Feb. 28, invisible in America but visible generally in Europe, Asia and Africa. It begins at $9^h\ 14^m$ A. M. and ends at $4^h\ 17^m$ P. M. Central Standard time. The magnitude of the eclipse is 0.871, i. e. that fraction of the Moon's diameter will be immersed in the Earth's shadow at the middle of the eclipse.

The third is the most important eclipse of the year, a *total eclipse of the Sun*, August 9. It will not be visible in the United States. The path of total eclipse starts in the Atlantic Ocean north of the British Isles, sweeps northeast across the northern parts of Norway and Sweden, eastward across the Arctic Ocean and the Island of Nova Zembla, thence southeast across Siberia

and the Japanese Island Yeso, ending in the Pacific Ocean, The duration of totality will be less than two minutes. The partial eclipse will be visible throughout western Europe, northern Asia, Greenland and Alaska. The regions in which the eclipse will be visible are laid down upon the accompanying chart.



TOTAL ECLIPSE OF AUGUST 8TH 1896.

There will doubtless be many expeditions sent out to observe this eclipse, the parties locating themselves along the center of the path of totality. The United States will not send a government expedition, but a private one has been organized by Professor D. P. Todd, the astronomer at Amherst College. A party of about twenty people, mostly scientists, will be conveyed to Japan in Mr. Arthur Curtis James' schooner yatch Coronet. They will observe the eclipse from the Island of Yeso.

English observers will no doubt most of them go to the coast of Norway to observe the eclipse. Those who simply wish to view the phenomenon will go to Bodö on the west coast, to which there will be many popular excursions. The eclipse here occurs so soon after sunrise that the altitude of the Sun will be too low for observations of scientific value. The scientific parties will probably most of them locate on the nortwest coast of Norway at a fishing station called Vadsö. "Here the duration of the eclipse is just two hours, and of totality 106 seconds. The Sun, too, has an altitude of 15°, or about that which it has at noon-day in England at midwinter. This is, of course, a very respectably elevation, and, given fine weather, a very satisfactory view of the eclipse should be obtained. But to get to Vadsö it is absolutely necessary that special arrangements should be made. We are not dealing with a fashionable sea-side resort, or with some commercial emporium on a great line of traffic. The Varanger Fjord lies right at the back of Europe, and Vadsö is just a fishing station well within the Arctic Circle, a settlement of the Hyperboreans at the back of the North Wind." We quote here from the address of the president to the *British Astronomical Association* at its annual meeting, October 30, 1895. He urges the necessity of the immediate organization of a special expedition by the Association. This address is very interesting and at another time we should like to give our readers the greater part of it. One more paragraph we will quote here.

"I would urge strongly upon those who have not yet entertained the idea of going, what an unusual opportunity is here presented to them. Of all the phenomena the changing heavens have to present to us, none rival in wonder and impressiveness a total solar eclipse. No celestial object is so utterly unique in its appearance as the corona; there is nothing to which it can be likened. And the chances of watching such an event are so rare. To see an eclipse we must travel; it is seldom, indeed, that we have one occur so near to our own doors. Surely it is the ambition of every astronomer, that, if it be any way possible, he

should watch at least one eclipse in the course of his life. The journey in this case is a short one, the eclipse falls in the middle of the holiday season, when most men can arrange to leave their engagements, and it certainly is not to be forgotten, that over and above the eclipse itself, and two short and pleasant voyages, there is the opportunity of seeing some of the finest and most sublime scenery in Europe in the Norwegian fjords."

All this applies particularly to those living in the British Isles and the adjacent parts of Europe, but it may apply as well to many Americans, who will be taking their vacation trips through the old world, and can with very little trouble arrange to take in one of the excursions to Norway to observe the eclipse. Doubtless there will be expeditions to the Island of Nova Zembla and to some points in Siberia.

For the benefit of those who may wish to calculate the phases of the eclipse the following data are given:

Greenwich mean time of conjunction in right ascension, August 9, $4^h\ 37^m\ 19^s.7$ A. M.

Sun and Moon's R. A.....	$9^h\ 17^m\ 57^s.53$	Hourly motions.....	$9^s.50$ and $137^s.95$
Sun's declination.....	$15°\ 44'\ 23''.4$N	Hourly motion.....	$0'\ 43''.68$
Moon's declination.....	$16\ 29\ 18\ .9$N	Hourly motion.....	$13\ 56\ .98$
Sun's equa. hor. par.....	$8\ .7$	Sun's true semi diam.	$15\ 48\ .0$
Moon's equa. hor. par.....	$59\ 28\ .0$	Moon's true "	$16\ 11\ .4$

The eclipse will begin Aug. 9 at $2^h\ 43^m.3$ A. M. Greenwich mean time, when the penumbra of the Moon's shadow touches the Earth at a point in Russia just north of the Black Sea. Central eclipse begins at $3^h\ 53^m.2$ A. M. off the coast of Norway; it will occur at noon in Siberia, at a point in longitude 111° 59′ E from Greenwich, at $4^h\ 37^m.3$ A. M. Greenwich time; and end at sunset in the Pacific Ocean at $6^h\ 25^m.3$ A. M. The last contact of the shadow with the Earth occurs in the Pacific Ocean, southeast of the Caroline Islands, at $7^h\ 34^m.9$ A. M.

A partial Eclipse of the Moon Aug. 22, will be visible throughout North and South America. The times of the phases are as follows:

		h	m		
Moon enters penumbra.....	Aug. 22	10	6.7	P. M.	Central Standard Time.
Moon enters shadow.....		11	24.5	"	
Middle of eclipse.....	23	12	57.5	A. M.	
Moon leaves shadow.....		2	57.5	"	
Moon leaves penumbra.....		3	47.9	"	

At the middle of the eclipse 0.735 of the Moon's diameter will be obscured. The data and graphical construction of this eclipse are given in the article by Professor Rigge in the December number of POPULAR ASTRONOMY.

The Planets.

Mercury begins the year as evening planet and will be at greatest elongation east from the Sun on the evening of January 23. He completes three synodical revolutions about the Sun in the year, and so will be at eastern elongation three times, Jan. 23, May 15 and Sept 13. At these times the planet will be visible to the naked eye for from 10 to 15 nights each, always setting within two hours after the Sun in our latitude. Mercury will be at inferior conjunction *i. e.*, between the Earth and the Sun, Feb. 8, June 9 and Oct. 8; at greatest western elongation Mar. 5, July 3, and Oct, 23; at superior conjunction, *i. e.*, behind the Sun, April 17, July 31 and Nov. 28.

Venus will be morning planet until July 9, when she will be at superior conjunction. After that she will be evening planet, gradually receding from the Sun, but not reaching greatest elongation until after the end of the year. The phase of Venus will therefore be gibbous, increasing to full in July, then decreasing for the remainder of the year. The last three months will be the best time for studying the markings of the planet, and these can be best studied in strong twilight or full sunlight.

Mars will not be in good position for observation until the middle of the year. He will be at quadrature, 90° west from the Sun Aug. 31; and during the remaining months we may expect to obtain good views of the planet. Opposition will occur on Dec. 10, when the distance of the planet from the Earth will be about 51,000,000 miles. Although this is considerable greater than the distance at the last opposition, in 1894, the greater northern declination and consequently greater altitude at which the planet may be observed this year will make up in great part for the increased distance. The diagram Fig. 1 shows the orbits of the two satellites of Mars as they will appear in an inverting telescope. Both satellites will pass in front of the planet from right to left and behind it from left to right. The circle represents the planet's disc on the same scale as the orbits. It is needless, perhaps, to remind the reader that these satellites can be seen only with large telescopes.

The course of Mars runs eastward through Scorpio and Sagittarius in January and February; northeast through Capricornus, Aquarius, Pisces, Aries and Taurus from March to October; turns backward, making a large loop in Taurus, during the remainder of the year.

Jupiter is to be observed in the evening during the first half of

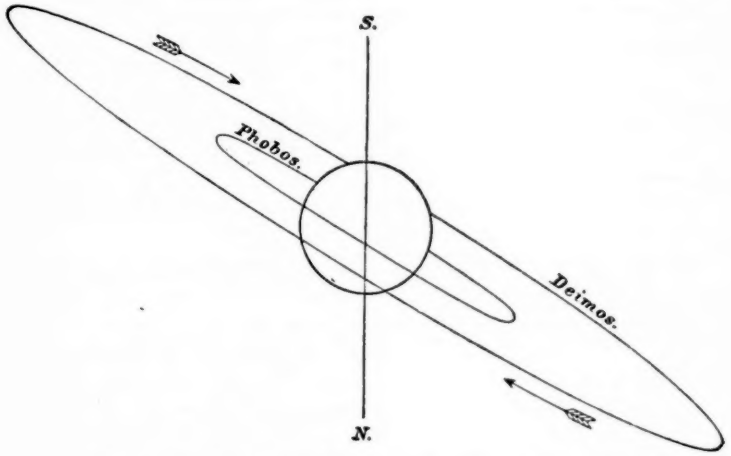


FIG. 1. APPARENT ORBITS OF THE SATELLITES OF MARS IN 1896.

the year. His opposition occurs Jan. 24, and conjunction with the Sun Aug. 12. During this time Jupiter remains in the constellation Cancer retrograding slowly until Oct. 25, then advancing, entering Leo in August. The belts of Jupiter and the four bright satellites may be observed with any good telescope, the satellites even with an opera-glass. Our readers will enjoy watching the changes of position of the satellites as well as the phenomena of their transits across the face of the planet and their passage behind it and through its shadow. The diagram, Fig. 2, shows the apparent courses of the satellites at the

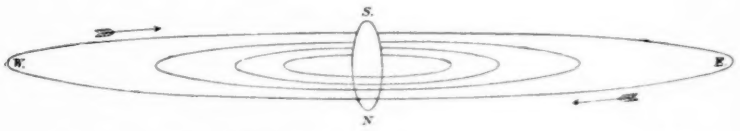


FIG. 2. APPARENT ORBITS OF THE FOUR BRIGHT SATELLITES OF JUPITER IN JANUARY, 1896.

beginning of the year. The vertical scale for the planet is three times and for the orbits five times the horizontal one, in order to separate the lines. The satellites all move in the direction indicated by the arrows, crossing the disc of the planet above the center. During the year the Earth will pass through the plane of the satellite orbits, so that their relative courses will apparently

change and will be represented in December by the Diagram, Fig. 3.

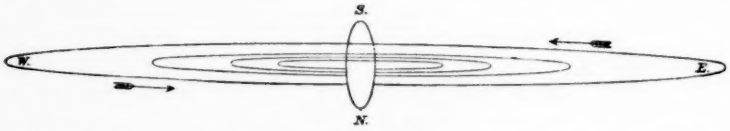


FIG. 3. APPARENT ORBITS OF THE FOUR BRIGHT SATTELLITES OF JUPITER IN DECEMBER, 1896.

The great red spot in Jupiter's southern hemisphere, which has been visible since 1878 is now very inconspicuous, although the notch in the southern edge of the great red belt marks its place distinctly. Remember that Jupiter rotates in 10 hours so that the spot is always visible at sometime in the night and at a different time each night. Many smaller red spots and white spots are to be observed upon the planet, and those who study them carefully find that their periods of rotation are not the same, showing that either these spots do not belong to the surface of Jupiter or that the planet has not a rigid crust like the Earth.

Saturn comes to opposition May 5 and will be most conveniently situated for observation from that time until September, but those who wish to get up in the morning may obtain pretty good views now. The course of the planet lies in the constellation Libra, eastward until Feb. 27, then westward until July 15, and eastward for the remainder of the year.

The rings of Saturn are now well situated for study, their plane making an angle of over twenty degrees with the line of sight. This will enable the observer easily to separate the two bright rings and to detect the faint, "gauzy," inner ring. Five of the eight satellites of Saturn will ordinarily be seen with a telescope of moderate size. The diagram, Fig. 4, shows the

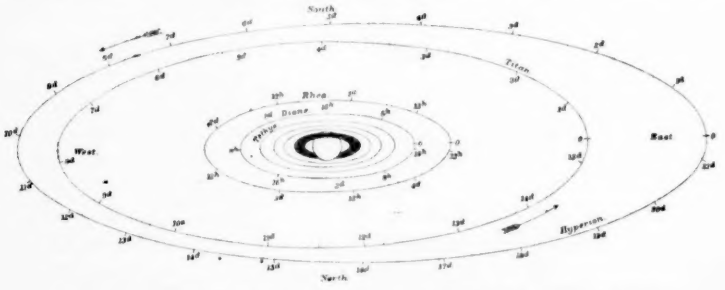


FIG. 4. APPARENT ORBITS OF THE SATELLITES OF SATURN IN 1896.

apparent orbits of all the satellites except Japetus, the outer one, for this year, and their positions in orbit at intervals of the indicated number of days after greatest eastern elongation.

Uranus is in nearly the same part of the sky with Saturn and so can be observed at the same time. His apparent course is a short one, back and forth on a line midway between α Libræ and β Scorpii. The four satellites are visible with the aid of large telescopes. Fig. 5 shows their apparent orbits during this year.

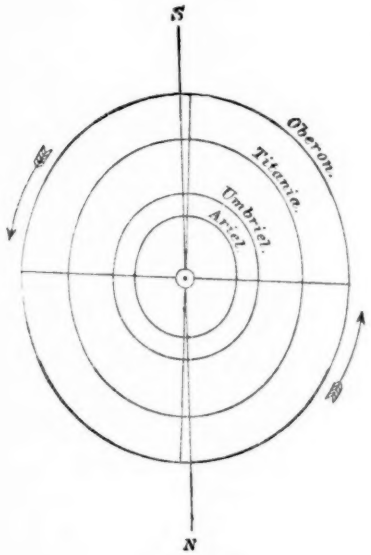


FIG. 5. APPARENT ORBITS OF THE SATELLITES OF URANUS IN 1896.

Neptune may be observed during the first three and the last three months of the year. He will be at quadrature March 5, at conjunction with the Sun June 7, at quadrature Sept. 12, and at opposition Dec. 10. His apparent course during the year is back and forth on a line, only five degrees long, in the constellation Taurus, between the stars ι and ζ. Fig. 6 shows the apparent orbit of Neptune's satellite for this year.

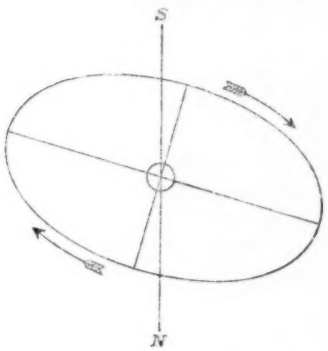


FIG. 6. APPARENT ORBIT OF THE SATELLITES OF NEPTUNE IN 1896.

THE MOON.

The following list of the times of the Moon's phases will enable us to plan beforehand our study of this most interesting of celestial bodies, which, though changing so rapidly in position and phase, yet presents, so far as positive evidence goes to show, an unchanging surface, however much the details of that surface

may appear to change under the varying illumination. Those who wish only casually to view the Moon will bear in mind that the best time to see craters and mountains distinctly is at about the first quarter.

New Moon.	First Quarter.	Full Moon.	Last Quarter.	Perigee.	Apogee.
			Jan. 7	Jan. 4	Jan. 19
Jan. 14	Jan. 22	Jan. 30	Feb. 5	Jan. 31	Feb. 16
Feb. 13	Feb. 21	Feb. 28	Mar. 6	Feb. 29	Mar. 14
Mar. 14	Mar. 22	Mar. 28	Apr. 4	Mar. 28	Apr. 10
Apr. 12	Apr. 20	Apr. 27	May 4	Apr. 26	May 8
May 12	May 20	May 26	June 3	May 24	June 5
June 11	June 18	June 25	July 2	June 20	July 2
July 10	July 17	July 24	Aug. 1	July 15	July 30
Aug. 8	Aug. 15	Aug. 23	Aug. 31	Aug. 11	Aug. 27
Sept. 7	Sept. 13	Sept. 21	Sept. 29	Sept. 8	Sept. 23
Oct. 6	Oct. 13	Oct. 21	Oct. 29	Oct. 6	Oct. 20
Nov. 5	Nov. 11	Nov. 20	Nov. 27	Nov. 4	Nov. 17
Dec. 4	Dec. 11	Dec. 19	Dec. 27	Dec. 2	Dec. 14
				Dec. 30	

Occultations.

Of these there will be the usual number. In the *American Ephemeris* 120 occultations are recorded as visible at Washington. The most noteworthy are two of Regulus (α Leonis) Jan. 23, $10^h\ 41^m$ to $11^h\ 44^m$ and Feb. 27, $7^h\ 49^m$ to $7^h\ 40^m$ Washington time; one of Mars on the morning of April 8, $2^h\ 48^m$ to $3^h\ 56^m$ A. M.; and one of Jupiter on the morning of July 12, $6^h\ 58^m$ to $7^h\ 52^m$ A. M., Washington time. The times of these occultations will need to be computed independently for each locality.

Sunspots.

As we are now about half way between the maximum and the minimum of the sunspot period we shall not expect to see very large nor great numbers of sunspots, but there will probably be few days in 1896 when the solar surface will be entirely free from spots.

Comets.

The only periodic comet to return to perihelion in 1896 is the one discovered by Mr. Brooks in 1889, which is now known as Comet 1889 V. This was found to be moving in a short ellipse, with a period of 7.07 years, and is due at perihelion on Oct. 27 this year. It will be favorably situated for observation during the summer months. Its orbit was so carefully determined that the comet will no doubt be found again, unless it has diminished a great deal in brightness. This is the comet that in 1886 passed through the satellite system of Jupiter and suffered such enormous changes of its orbit. Since 1889 there have been no serious perturbations of its path and we may expect it to return pursu-

ing a similar course to that in 1889. In that year three faint companion comets were seen, fragments perhaps separated from the parent mass by the influence of Jupiter and his moons. It will be interesting to see if any of these can be found again.

New comets of course may be expected at any time. Let us hope that a great one may appear, worthy of the splendid appliances with which astronomers may now study these startling and wonderful visitors from the regions of interstellar space.

COMET *c* 1895, (PERRINE.)

C. D. PERRINE.

For Popular Astronomy.

On the morning of November 17, at 5:30 I picked up a bright comet in the constellation *Virgo*. It was twilight then so that an observation of position was not possible. Several pointings were taken and an approximate discovery position of, $\alpha = 13^h\ 44^m$ and $\delta = +1^\circ\ 40'$, was announced.

The comet was quite bright, with a well defined stellar nucleus which was estimated at about 7 magnitude, and with a short tail probably 10′ long.

On the morning of November 18, a position was secured and then I was called away from the Observatory. The positions for the next few mornings were secured by Prof. Aitken. I returned to the observatory on November 23 and have since been Observing it, and noticed that a very marked increase in brightness had taken place during my absence. On the morning of November 26th it was clearly visible to the naked eye and is rapidly increasing in brightness.

From observations on the mornings of November 18, 19, 20, Professor Campbell has computed an orbit and obtains the following parabolic elements.

$$T = \text{December } 18.4063$$
$$\left.\begin{aligned} \omega &= 273^\circ\ 01' \\ \Omega &= 320^\circ\ 49' \\ i &= 141^\circ\ 25' \end{aligned}\right\} 1895.0$$
$$q = 0.1914$$

Residuals for middle place:

$$\text{Obs'd-Comp.} \quad \left\{\begin{aligned} \cos\beta' \ \Delta\lambda' &= -0'.02 \\ \Delta\beta' &= -0\ .04 \end{aligned}\right.$$

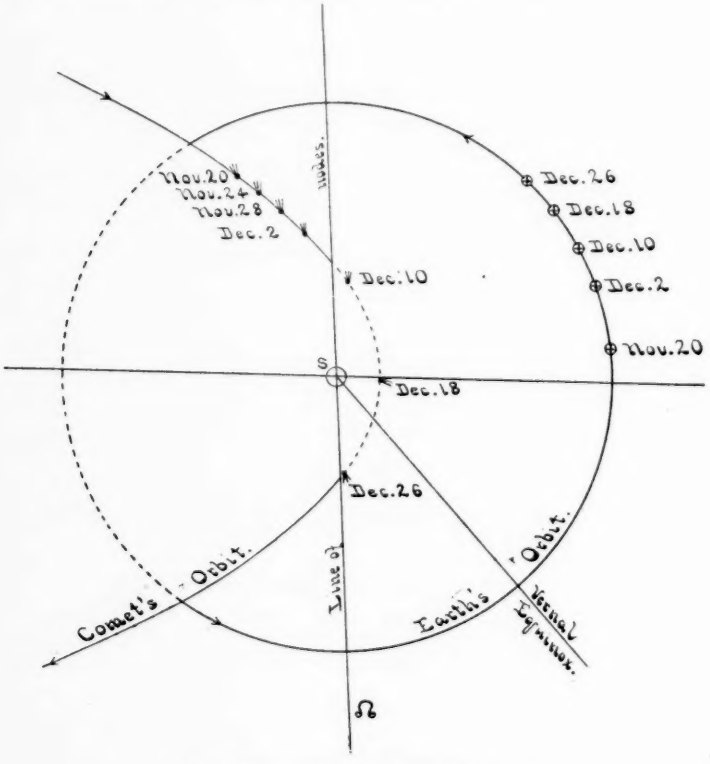
The following short ephemeris is from the above elements:

	α			δ	
	h	m	s	°	′
November 20.5	13	52	14	−0	7.7
24.5	14	2	52	−2	36.3
28 5	14	16	27	−5	43.1
December 2 5	14	34	52	−9	45.7
10	15	45		−22	
18.5	18	15		−31	
26	19	10		−23	

Greenwich M. T.

The light on Dec. 2 will be about six times as bright as at discovery.

From the same observations of Nov. 18, 19 and 20, an orbit was computed by the advanced class in astronomy at the University of California under Professor Leuschner, which agrees very satisfactorily with Professor Campbell's orbit.



THE ORBIT OF COMET *c* 1895 (PERRINE).

In a week or two a new orbit will be computed from observations at wider intervals. An orbit from one day intervals must be considered as somewhat approximate.

The comet has been regularly photographed by Mr. Colton, using a Willard lens of 5¼ inches aperture and 28 inches focus. The photograph of November 18 shows a tail 1° long while on the last one secured (November 26) the tail is 5° long. There is a second short tail north of and making an angle of about 30° with the longer one. The short tail is intrinsically the brightest. There are evidences of other short streamers emanating from the head, but as yet they are very faint.

Professor Campbell has observed its spectrum which he finds of the usual type, *i. e.*, consisting of a faint continuous spectrum and the bright lines and bands showing the presence of incandescent carbon and nitrogen.

The accompanying diagram is an orthographic projection of the comet's orbit onto the plane of the ecliptic, showing the position of the comet in its orbit and the corresponding positions of the Earth. It will be noticed that the motion is "retrograde."

The comet becomes an evening object about December 15, but will probably be lost in the Sun's rays for several days. It will not recede very far from the Sun and will again become a morning object about January 5. The comet will, therefore, be much better situated for observation before its perihelion passage than after.

LICK OBSERVATORY, November 29, 1895.

THE GRAPHIC CONSTRUCTION OF ECLIPSES AND OCCULTATIONS.

II.—SOLAR ECLIPSES.

WM. F. RIGGE, S. J.

FOR POPULAR ASTRONOMY.

A solar eclipse is produced by the passage of the Moon between the Earth and Sun in such a way as to partially or completely obscure the solar disk. The shadow cast by the Moon is a cone, a geometrical solid, whose vertex, owing to the varying distance of the Moon, may, first, not reach the sunward side of the Earth at all, or, secondly, it may reach, or geometrically speaking, pass

into or through the Earth. In the former case the eclipse is annular, and in the latter, total.

Besides its shadow cone, within which the Sun is totally eclipsed, the Moon is also enveloped in a penumbral cone, within which the eclipse is partial. The vertex of this penumbral cone is between the Sun and Moon, and its cross section continually increases as it recedes from the Moon towards and beyond the Earth. It is this penumbral cone that we have to deal with principally when we speak of constructing a solar eclipse.

In order that our treatment of the subject may be clear and simple, and that our diagrams may not be merely a mathematical conception but represent a true physical fact, we shall imagine ourselves transported to the Sun and looking down upon the Earth while the Moon's shadow and penumbra are sweeping across it. The Earth, the Moon and the penumbra will then all appear to be circles projected upon a plane at right angles to the line of sight, so that we again have the case of one circle moving over another. Owing to the Earth's rotation the paths of points on its surface will appear to be ellipses. The construction of a diagram of a solar eclipse for a given place then amounts to this: we must plot the elliptical path across the Earth's sunlit disk of the place for which the eclipse is to be constructed, and note its positions thereon at various times so that we may know its exact location at any moment; we must then lay down the path of the penumbra and know its positions at corresponding times; and finally we must ascertain from our drawing the exact instant at which the edge of the penumbra overtakes and leaves the place in question. These are the instants at which the eclipse begins and ends at that place.

The construction therefore is not difficult, and even the ellipse can be easily and accurately drawn according to the method we shall explain. So that our main object will be to become acquainted with the terms and to learn what to do.

In order to exemplify the process we shall take a particular eclipse and plot it for a particular place. The reader will then know how to apply the elements of the same or any eclipse to any other place.

The eclipse we shall select is the one of July 29, 1897. As this eclipse will be visible all over the United States and is sufficiently remote to allow us to prepare for it, some of our readers may take the opportunity to plot it for their own locality. To add to the interest, we may mention that within the United States the magnitude of the eclipse will be very different for different places,

ranging all the way from one tenth in the state of Washington to the annular phase off the extremity of Florida. The duration, and the times of beginning, middle and end will also be different, as well as the position angles of the points of contact. For, a solar eclipse is essentially a local phenomenon; it is not like a lunar eclipse, a picture hung up in the sky exposed to the view of half the world, but the Moon's shadow aud penumbra fall only on certain sections of the Earth and move over them successively, and each place of observation has its own individual position and motion, so that no two places on the Earth can have exactly the same view of the same solar eclipse. In the sixth and last article of this series will be found maps showing the times of the phases to the nearest minute, as also the magnitude of the eclipse for the entire United States. These may then serve as tests of the accuracy of their work, if time and inclination should lead some of our readers to plot this eclipse for their own places of residence.

As to the place for which we shall construct the eclipse, we shall select St. Louis. Its latitude, φ, is $+ 38^\circ 38'$, and its longitude from Greenwich is $+ 6^h 1^m$. For other places ordinary state maps will furnish the geographical co-ordinates with more than the necessary precision, because the nearest quarter of a degree is sufficient for the latitude, and the nearest minute of time for the longitude.

The Earth's Disk. Let us now turn our attention to Fig. I. Let the reader not be disheartened by its apparent intricacy. For the sake of explanation more lines have been drawn on it than are necessary in practice, but with a little patience everything will be unravelled and made clear. The large circle which has the cardinal points marked at the extremities of the axes, is the Earth's disk as seen from the Sun. We shall call its radius unity. As to the actual length of this radius in inches, we shall find $3\frac{1}{3}$ inches, or 10 times one third of an inch (the largest unit but one generally given on the common plotting scales) a very convenient length in practice. The diagrams accompanying this article were drawn on this scale, but they had to be reduced to adapt them to the pages of this periodical.

The plane upon which the diagram is supposed to be drawn, passes through the Earth's center at right angles to the line joining the Earth and Sun. It consequently bisects the Earth into the illuminated and dark, or the diurnal and nocturnal hemispheres. The Earth's axis is in this division plane only twice a year, at the time of the equinoxes, when both poles are illuminated. During our spring and summer the north pole lies in the illuminated hemisphere. The inclination of the Earth's axis to

this plane, which is called the fundamental plane, is the same as the Sun's declination, δ, as will appear from Fig. II,* which gives a view of the Earth at right angles to its axis and to the Sun. In the eclipse we are investigating, $\delta = +\ 18^\circ\ 36'$ (Ephemeris, p. 412), and as it is summer (July 29), the north pole is in the illuminated hemisphere (point P in Fig. I) and the equator is tilted downward in the drawing.

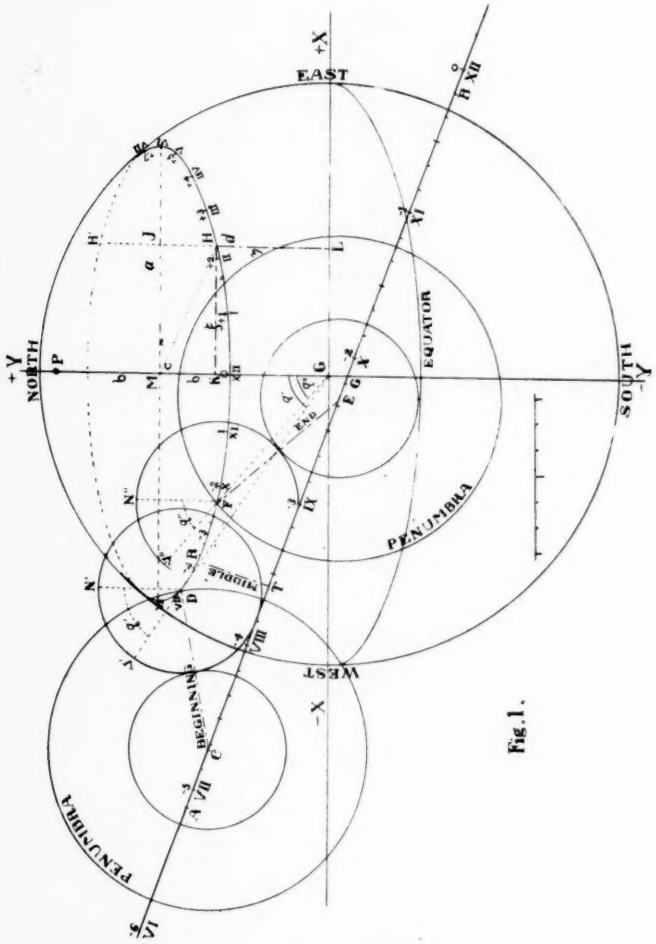


Fig. I.

The Path of St. Louis. Owing to the rotation of the Earth,

* Fig. II will appear in next number.

every point on its surface describes a circle whose radius is the radius of the Earth multiplied by cos φ, φ being the latitude of the place, or simply cos φ in our diagram, since the radius of the Earth's disk has been taken as our unit and all quantities are to be expressed by reference to it.

The circular path of St. Louis, seen from the Sun, will appear as an ellipse whose semi-major axis, not being foreshortened by the projection, is $a = \cos \varphi = \cos 38° 38' = 0.782$, and whose semi-minor axis is $b = \cos \varphi \sin \delta = \cos 38° 38' \times \sin 18° 36' = 0.250$, as will be evident from a study of Figs. I and II. The major axis is parallel to the axis of X, and the center of the ellipse, M, is on the axis of Y at the distance $MQ = d = \sin \varphi \cos \delta = \sin 38° 38' \times \cos 18° 36' = 0.589$ from the center of the disk. The minor axis is a maximum at the solstices, and a minimum, that is, zero, at the equinoxes.

The ellipse is not wholly visible from the Sun, but only its sunlit or diurnal part, which is more than half in summer and less than half in winter. In summer (as in the present eclipse) the visible part is tilted downward and in winter upward. The dotted upper portion of the ellipse in Fig. I represents not only the completed ellipse, that is, the nocturnal path of St. Louis on July 29 as it would be seen if the Earth were transparent, but also the winter path on the day when the Sun's declination is $-18° 36'$ instead of $+18° 36'$ as it is in the present case. The ellipse must, of course, be tangent to the disk in two points, the points of sunrise and sunset. The ordinates (that is vertical distances above the axis of X) of these points, it is useful to know, are equal to sin φ sec δ.

As we must know the position of St. Louis on its ellipse at any given time, it will be easiest in practice to determine these points first, and then to draw the ellipse through them. St. Louis is at the place marked O or XII or on the axis of Y at local apparent noon. Remembering that the ellipse is the projection of a circle, we shall understand after a little study that if τ is the angle (in the plane of the circle) through which the Earth has turned since the place appeared on the axis of Y, that is in other words, if τ is the local apparent solar time at a chosen moment, then the abscissa or horizontal distance of the place H from the axis of Y is $KH = \xi = a \sin \tau = \cos \varphi \sin \tau$, and its ordinate or vertical distance above the axis of X is $LH = \eta = LJ - JH = d - b \cos \tau = \sin \varphi \cos \delta - \cos \varphi \sin \delta \cos \tau$. This value of η is to be taken algebraically, so that when δ (and consequently sin δ) is negative, the sign of the second term is reversed and we shall have

$LH' = LJ + JH'$. This agrees with what has been said before, that in autumn and winter (when δ is negative) the ellipse is tilted upward.

Having located the extremities of the axes of the ellipse, we next compute and plot the position of St. Louis for every hour of apparent solar time, or when τ is equal to 1, 2, 3, 4, 5 hours or 15, 30, 45, 60, 75 degrees. This will furnish us with five additional points on either side of the axis of Y, because an ellipse is symmetrical with regard to its axes. In computing and plotting the vertical distances we shall for the sake of convenience start from the major-axis of the ellipse instead of from the axis of X, that is, we shall lay off JH or $b \cos \tau$ instead of LH or $d - b \cos \tau$. The logarithmic computation of these five points, together with the construction of the ellipse, ought not after a little practice to consume more than ten minutes. It is the longest computation we shall be obliged to make for this eclipse.

For the sake of greater convenience in our work, we write the values of log sin τ and log cos τ in two parallel columns using only four-place logarithms. Then taking a slip of paper and writing

τ	sin	cos
1	9.4130	9.9849
2	9.6990	9.9375
3	9.8495	9.8495
4	9.9375	9.6990
5	9.9849	9.4130
	9.8933	9.3970
	log a	log b

log a and log b on its upper edge, we hold the slip to this little table so that log a will come under log sin τ for 1 hour (9.4130) and log b under log cos τ for the same hour (9.9849). Adding up mentally log a and log sin τ, we look in a four-place logarithm table for the natural number, take out only the first three figures at sight, and then open a pair of dividers to this amount on the plotting scale. If we cannot add two numbers beginning at the left, it will be necessary of course, to write down their sum before looking in the table. Adding in the other way, from left to right, saves time and writing. It may be acquired with a little practice, as all one has to do is to look ahead and see whether the sum of a pair of digits is to be increased or not by the 1 which may have to be carried forward from the sum of the next pair to the right. We find $b \cos \tau$ in the same way we have used for $a \sin \tau$, and open a second pair of dividers to its value. Taking the two dividers one in each hand, and starting from the center of the ellipse, we lay off the abscissa ($a \sin \tau$, the first number found) to

the right and left on the major axis, and mark its extremity with a fine dot. We do the same to the ordinate ($b \cos \tau$) on the minor axis, laying it off only downward (or upward for a winter eclipse), because the other or nocturnal part of the ellipse is of no utility. Then putting one leg of each of the dividers into the impression made by the other, we find a point into which the other legs will both fit. This is a point of the ellipse, and should be secured and rendered visible by a little circle drawn about it in lead pencil. With the same opening of the dividers we find the corresponding point on the other side of the axis of Y. Then moving the slip of paper which contains the values of log *a* and log *b* to the next value of τ, we proceed in a similar manner. Drawing a smooth curve through the points we have determined, we have not only the path of St. Louis for that day, but also its exact position at every hour. The half hours and ten minutes may then be plotted with sufficient accuracy by mere estimation.

The Path of the Moon or Penumbra. The next thing is to plot the path of the Moon or penumbra across the Earth's disk. This is easily done with the help of the data given by the Ephemeris on page 415. We take two points on the path some four or five hours apart, and plot them. We have taken A at $1^h\ 0^m$ Greenwich time, and B at $6^h\ 0^m$. The co-ordinates of A are $x = -1.495$, $y = +0.481$, and of B $x = +0.999$, $y = -0.438$. After plotting these points, we draw the straight line A B through them. It is the path of the penumbra.

But as in the case of the path of St. Louis, we must know the moon's position at every hour and fraction, and we must express this in the same terms, that is, in St. Louis apparent solar time. As the Moon moves with practically uniform velocity during the time it takes to cross the Earth's disk, we measure the distance from A to B, the Moon's positions at 1^h and 6^h Greenwich time, and take one fifth of it for the moon's motion in an hour. This distance divided into 10 minute spaces is represented in the lower part of Fig. I. We must next know the Moon's position at a given hour of St. Louis time.

The Moon crosses the axis of Y at the point G, that is, it is in conjunction with the Sun, at $3^h\ 59^m\ 47^s.5$ or $4^h\ 0^m$ Greenwich mean time (Ephemeris, p. 412). Subtracting the longitude of St. Louis, $+ 6^h\ 1^m$, and adding the equation of time, $- 6^m$, (Ephemeris, p. 111), we have $- 2^h\ 7^m$ as the St. Louis apparent solar time of conjunction, or in more convenient terms, $9^h\ 53^m$ A. M. Applying our scale of hourly motion to the Moon's orbit in such a way that the point G reads 53 minutes, we mark the full hours

IX and X and the 10 minutes, and then shifting our little measuring staff, we plot all the hours and 10 minute spaces between A and B, or beyond them if necessary. As a test of the accuracy of this part of the work we may observe, that as A and B are 5 full hours apart in Greenwich time, they ought also be 5 full hours apart in St. Louis time. It may not be necessary to remark that the Moon's motion is from west to east, that is, from left to right on the diagram.

Times of the Phases. We are now in a position to gather the fruits of our labor and determine the times of the beginning, middle and end of the eclipse. We know the exact individual positions of the center of the penumbra and of St. Louis at any time, it only remains to ascertain whether and when the penumbra will overtake St. Louis, and also how near this place will approach to the penumbra's center. The penumbra evidently overtakes St. Louis at the instant when the distance of St. Louis from the penumbra's center is equal to the latter's semi-diameter. With our dividers or compass opened to 0.553, the radius of the penumbra (Ephemeris, p. 415), we try to find two points, one on the Moon's path and the other on the ellipse, which show equal times. We shall find that this is the case when the penumbra is at the point C and St. Louis at D, both reading $7^h\ 17^m$ on their respective paths. The eclipse therefore begins at St. Louis at $7^h\ 17^m$ A. M. local apparent solar time. As the Sun is 6 minutes slow on that day, July 29, (Ephemeris, p. 110), this is $7^h\ 23^m$ mean time, or $7^h\ 24^m$ Central time, because St. Louis is 1^m west of the 90th meridian.

The time of the end of the eclipse is ascertained in a similar way, that is, by finding two points, one on each path which show equal times and are 0.553 apart. These are the points E and F. The eclipse therefore ends at St. Louis at $9^h\ 43^m$ A. M. apparent time, or $9^h\ 49^m$ mean time, or $9^h\ 50^m$ Central time.

The time of the middle of the eclipse is that instant when the obscuration is a maximum, that is, when the place of observation is nearest the centre of the penumbra. This time is not necessarily halfway between the times of beginning and ending, because, although the motion of the Moon may be uniform, the motion of the projection of St. Louis on the fundamental plane is not so, as will appear from an examination of its hourly positions on the ellipse. Nor does the place move always in the same direction with respect to the Moon's path. Hence the time of the middle of the eclipse must be determined by a special measurement on the diagram. We try to find the two points, one on

each path, which show equal times and are nearest together. These are the points T and R, which show that the middle of the eclipse at St. Louis will occur at $8^h\ 25^m$ A. M. apparent time, or $8^h\ 31^m$ mean time, or $8^h\ 32^m$ Central time.

If we should have the good fortune to be situated so near to the central line of the eclipse as to be able to observe the total or annular phase, we should find two points, one on the Moon's path and the other on the ellipse, which show equal times and which are separated by a distance equal to the radius of the positive, or negative shadow of the Moon on the Earth, understanding by the positive shadow the true shadow in a total eclipse, and by the negative shadow the prolongation of the shadow cone in an annular eclipse, within which prolongation the Sun is seen all around the Moon. This radius is almost too small to be perceptible on our diagram, being only 0.008 in the present eclipse (Ephemeris p. 415), which, as we have said, is annular. In order therefore to determine the instants of the beginning and end of the total or annular phase, we must either enlarge the scale of our diagram or have recourse to rigorous computation. That our place of observation will really be able to see this phase of the eclipse will appear from the fact that the Moon's path on the diagram intersects or is tangent to the ellipse at a point which shows equal times on both. Only the central part of Mexico and a portion of the northern shore of Cuba, as also a number of the small islands in the West Indies, and Cape S. Roque in Brazil, and the intervening waters, will enjoy this rare celestial spectacle on July 29, 1897.

[To Be Continued.]

THE PLANETS AND THE CONSTELLATIONS FOR JANUARY.

Mercury is evening planet during January and will be visible to the naked eye from about the 15th to the 30th. Those who wish to see Mercury will look toward the southwest about an hour after sunset. They will see the planet down near the horizon, as bright as a star of the first magnitude. It will be among the faint stars of Capricorn, so that none can be mistaken for the planet. During these days the phase of Mercury will change from gibbous to crescent, over three quarters of the disc being illuminated Jan. 15 and only about one quarter on the 30th.

Venus is "morning star" and is moving away from the Earth. Her gibbous phase increases from 0.652 to 0.754 during the month, while her light diminishes from 108 to 82. The position of Venus on Jan. 5 is: R. A. $15^h\ 39^m.9$; Decl. $-16°\ 51'$; on Jan. 15: R. A. $16^h\ 48^m.7$; Decl. $-20°\ 10'$; Jan. 25: R. A. $17^h\ 38^m.4$; Decl. $-21°\ 35'$.

Mars may be seen in Scorpio in the morning, but is so distant from the Earth, that it will not be worth while for the observer to spend any time looking at this planet.

THE PLANETS AND THE ZODIAC FOR JANUARY.

Jupiter comes opposite to the Sun this month and may be seen all night. Opposition occurs Jan. 24. The planet is in the constellation Cancer which is shown upon our map for this month. At 9 o'clock P. M. Jupiter will be toward the east, about half way up to the zenith, and so in good position to be studied during the remainder of the night. The planet is so bright that we need not give its right ascension and declination. The great red spot will be near the central meridian of Jupiter's disc at the following times:

Jan. 1	8 P. M.	Jan. 11	6 P. M.	Jan. 22	2 A. M.
3	1 A. M.	12	midn.	22	10 P. M.
3	9 P. M.	13	7 P. M.	23	6 P. M.
5	3 A. M.	15	1 A. M.	24	midn.
5	11 P. M.	15	9 P. M.	25	7 P. M.
6	7 P. M.	17	3 A. M.	27	1 A M.
7	midn.	17	11 P. M.	27	9 P. M.
8	8 P. M.	18	7 P. M.	29	3 A. M.
10	2 A. M.	19	midn.	29	11 P. M.
10	10 P. M.	20	8 P. M.	30	6 P. M.
				31	midn.

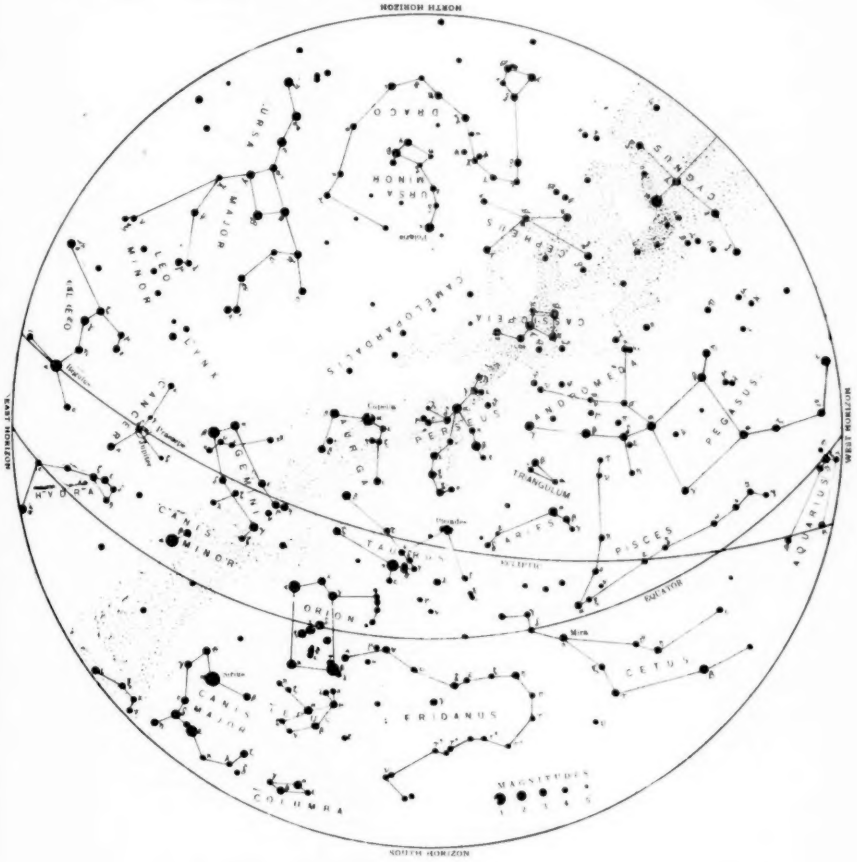
In another place we give the list of phenomena of Jupiter's four bright satellites. The fifth satellite will be too faint for our readers to see.

A few words of explanation of the table of phenomena may be of use here. The first column gives the date, hour and minute of Central Standard time, the second the Roman numeral by which the satellite is designated, the third the initial letters of the phenomenon, Ec. for eclipse, Oc. for occultation, Tr. for transit of the satellite, Sh. for transit of the shadow. In the last column Dis. stands for

disappearance of the satellite at the beginning of eclipse or occultation; Re. for reappearance after eclipse or occultation; In. for ingress upon, and Eg. for egress from, the disc of the planet. For instance, the first phenomenon which can be observed in the United States is recorded in the table

Jan. 1 9^h 59^m P. M. II* Ec. Dis.

which is interpreted as follows: On January 1 at 9^h 59^m P. M. satellite II will disappear, being eclipsed in the shadow of the planet. The * indicates that this phenomenon will be visible at Washington. In the next line we find that satellite II will reappear from occultation behind the planet at 1^h 58^m A. M. Jan. 2. The disappearances always occur at the left (as seen in an inverting telescope) side of the planet and the reappearances at the right.



THE CONSTELLATIONS AT 9 O'CLOCK P. M. FOR JANUARY 1.

Saturn and *Uranus* are not yet in favorable position for observation.

Neptune is in good position and may be observed best from 8^h P. M. to 2 A. M. The right ascension of Neptune on Jan. 15 will be 4^h $58^m.4$ and the declination $+ 21° 13'$. The apparent motion is westward about 5′ per day.

Jupiter's Satellites for January.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.

III.

II.

IV.

Configuration 11h 30m for an Inverting Telescope.

Day.	West.	East.
1	·4	○ ·1 ·3 ·2●
2	·4 ·1	○ 2· ·3
3	2 4	○ 1·3·
4	·23· ·1	○ ·4
5	3·	○1. ·2 ·4
6	·3	○ 2· ·4 .1●
7	2· 1· ·3	○ ·4
8	·2	○ ·1 ·3 4·
9	1·	○ ·2 3· 4·
10	2·	○ 1· ·3 4·
11	·2 3 ·1	○ 4·
12	3· 4·	○ 1· ·2
13	4 ·3	·1○ 2·
14	4· 2· 31·	○
15	4· ·2	○ ·1 ·3
16	·4 1·	○ ·2 ·3
17	○2· ·4	○ ·1 3·
18	·4 ·2 ·1 3·	○
19	3· ·4	○ 1· ·2
20	·3 ·1	○ 2· ·4●
21	○1· 2· ·3	○ ·4
22	·2	○ ·1 ·3 ·4
23	1·	○ ·2 ·3 ·4
24		○2· ·1 3· ·4
25	○3· ·2 ·1	○ 4·
26	3·	○ ·2 1· 4·
27	·3 ·1	○ 2 4·
28	2· ·3	○1·4·
29	4· ·2	○ ·3 1●
30	4· 1.	○ ·2 ·3
31	4·	○ 2· ·1 3·

Phenomena of Jupiter's Satellites.

Central Time.

Jan.	1	2	6	P. M.	I	Ec. Dis.
		4	57	"	I	Oc. Re.
		9	59	"	II*	Ec. Dis.
	2	1	58	A. M.	II*	Oc. Re.
		11	24	"	I	Sh. In.
		11	56	"	I	Tr. In.
		1	44	P. M.	I	Sh. Eg.
		2	16	"	I	Tr. Eg.
	3	8	35	A. M.	I	Ec. Dis.
		11	23	"	I	Oc. Re.
		4	9	P. M.	II	Sh. In.
		5	9	"	II	Tr. In.
		7	3	"	II*	Sh. Eg.
		8	4	"	II*	Tr. Eg.
	4	1	41	A. M.	IV*	Ec. Dis.
		5	52	"	I*	Sh. In.
		6	7	"	IV	Ec. Re.
		6	15	"	IV	Oc. Dis.
		6	21	"	I	Tr. In.
		8	12	"	I	Sh. Eg.
		8	22	"	III	Sh. In.
		8	41	"	I	Tr. Eg.
		10	18	"	III	Tr. In.
		10	58	"	IV	Oc. Re.
		11	59	"	III	Sh. Eg.
		1	58	P. M.	III	Tr. Eg.
	5	3	3	A. M.	I*	Ec. Dis.
		5	49	"	I*	Oc. Re.
		11	17	"	II	Ec. Dis.
		3	6	P. M.	II	Oc. Re.
	6	12	21	A. M.	I*	Sh. In.
		12	47	"	I*	Tr. In.
		2	40	"	I*	Sh. Eg.
		3	7	"	I*	Tr. Eg.
		9	32	P. M.	I*	Ec. Dis.
	7	12	15	A. M.	I*	Oc. Re.
		5	26	"	II*	Sh. In.
		6	16	"	II	Tr. In.
		8	20	"	II	Sh. Eg.
		9	11	"	II	Tr. Eg.
		6	49	P. M.	I*	Sh. In.
		7	13	"	I*	Tr. In.
		9	9	"	I*	Sh. Eg.
		9	33	"	I*	Tr. Eg.
		10	17	"	III*	Ec. Dis.
	8	3	29	A. M.	III*	Oc. Re.
		4	0	P. M.	I	Ec. Dis.
		6	41	"	I*	Oc. Re.
	9	12	35	A. M.	II*	Ec. Dis.
		4	13	"	II*	Oc. Re.
		1	18	P. M.	I	Sh. In.
		1	40	"	I	Tr. In.
		3	37	"	I	Sh. Eg.
		4	0	"	I	Tr. Eg.
	10	10	29	A. M.	I	Ec. Dis.
		1	7	P. M.	I	Oc. Re.
		6	44	"	II*	Sh. In.
		7	23	"	II*	Tr. In.
		9	38	"	II*	Sh. Eg.
		10	18	"	II*	Tr. Eg.
	11	7	46	A. M.	I	Sh. In.
		8	5	"	I	Tr. In.
		10	6	"	I	Sh. Eg.
		10	25	"	I	Tr. Eg.
		12	20	P. M.	III	Sh. In.
		1	35	"	III	Tr. In.
		3	57	"	III	Sh. Eg.
		5	15	"	III	Tr. Eg.
	12	4	57	A. M.	I*	Ec. Dis.
		7	33	"	I	Oc. Re.
		10	1	"	IV	Sh. In.
		12	42	P. M.	IV	Tr. In.
		1	53	"	II	Ec. Dis.
		2	37	"	IV	Sh. Eg.
		5	21	"	II	Oc. Re.
		5	25	"	IV	Tr. Eg.
	13	2	15	A. M.	I*	Sh. In.
		2	31	"	I*	Tr. In.
		4	35	"	I*	Sh. Eg.
		4	52	"	I*	Tr. Eg.
		11	26	P. M.	I*	Ec. Dis.
	14	1	59	A. M.	I*	Oc. Re.
		8	1	"	II	Sh. In.
		8	30	"	II	Tr. In.
		10	55	"	II	Sh. Eg.
		11	25	"	II	Tr. Eg.
		8	43	P. M.	I*	Sh. In.
		8	57	"	I*	Tr. In.
		11	3	"	I*	Sh. Eg.
		11	18	"	I*	Tr. Eg.
	15	2	16	A. M.	III*	Ec. Dis.
		6	46	"	III	Oc. Re.
		5	54	P. M.	I*	Ec. Dis.
		8	25	"	I*	Oc. Re.
	16	3	11	A. M.	II*	Ec. Dis.
		6	28	"	II	Oc. Re.
		3	12	P. M.	I	Sh. In.
		3	23	"	I	Tr. In.
		5	31	"	I*	Sh. Eg.
		5	44	"	I*	Tr. Eg.
	17	12	23	"	I	Ec. Dis.
		2	40	"	I	Oc. Re.
		9	18	"	II*	Sh. In.
		9	37	"	II*	Tr. In.
	18	12	13	A. M.	II*	Sh. Eg.
		12	32	"	II*	Tr. Eg.
		9	40	"	I	Sh. In.
		9	49	"	I	Tr. In.
		12	0	M.	I	Sh. Eg.
		12	10	P. M.	I	Tr. Eg.
		4	18	"	III	Sh. In.
		4	51	"	III	Tr. In.
		7	56	"	III*	Sh. Eg.
		8	31	"	III*	Tr. Eg.
	19	6	51	A. M.	I	Ec. Dis.
		9	16	"	I	Oc. Re.
		4	29	P. M.	II	Ec. Dis.
		7	35	"	II*	Oc. Re.
	20	4	9	A. M.	I*	Sh. In.
		4	15	"	I*	Tr. In.

	6	29	"	I	Sh. Eg.
	6	35	"	I	Tr. Eg.
	7	42	P. M.	IV*	Ec. Dis.
21	1	7	A. M.	IV*	Oc. Re.
	1	20	"	I*	Ec. Dis.
	3	42	"	I*	Oc. Re.
	10	35	"	II	Sh. In.
	10	44	"	II	Tr. In.
	1	29	P. M.	II	Sh. Eg.
	1	39	"	II	Tr. Eg.
	10	38	"	I*	Sh. In.
	10	41	"	I*	Tr. In.
22	12	58	A. M.	I*	Sh. Eg.
	1	1	"	I*	Tr. Eg.
	6	15	"	III	Ec. Dis.
	10	1	"	III	Oc. Re.
	7	48	P. M.	I*	Ec. Dis.
	10	8	"	I*	Oc. Re.
23	5	46	A. M.	II	Ec. Dis.
	8	42	"	II	Oc. Re.
	5	6	P. M.	I	Sh. In.
	5	7	"	I	Tr. In.
	7	26	"	I*	Sh. Eg.
	7	27	"	I*	Tr. Eg.
24	2	14	"	I	Oc. Dis.
	4	34	"	I	Oc. Re.
	11	51	"	II*	Tr. In.
	11	53	"	II*	Sh. In.
25	2	46	A. M.	II*	Tr. Eg.
	2	48	"	II*	Sh. Eg.
	11	33	"	I	Tr. In.
	11	35	"	I	Sh. In.
	1	53	P. M.	I	Tr. Eg.
	1	54	"	I	Sh. Eg.
	8	6	"	III*	Tr. In.
	8	18	"	III*	Sh. In.
	11	46	"	III*	Tr. Eg.
	11	56	"	III*	Sh. Eg.
26	8	40	A. M.	I	Oc. Dis.
	11	1	"	I	Ec. Re.
	6	54	P. M.	II*	Oc. Dis.
	9	54	"	II*	Ec. Re.
27	5	59	A. M.	I	Tr. In.
	6	4	"	I	Sh. In.
	8	19	"	I	Tr. Eg.
	8	24	"	I	Sh. Eg.
28	3	6	"	I*	Oc. Dis.
	5	29	"	I	Ec. Re.
	12	58	P. M.	II	Tr. In.
	1	11	"	II	Sh. In
	3	53	"	II	Tr. Eg.
	4	6	"	II	Sh. Eg.
29	12	25	A. M.	I*	Tr. In.
	12	32	"	I*	Sh. In.
	2	45	"	I*	Tr. Eg.
	2	47	"	IV*	Tr. In.
	2	52	"	I*	Sh. Eg.
	4	0	"	IV*	Sh. In.
	7	30	"	IV	Tr. Eg.
	8	37	"	IV	Sh. Eg.
	9	37	"	III	Oc. Dis.
	1	43	P. M.	III	Ec. Re.
	9	32	"	I*	Oc. Dis.
	11	58	"	I*	Ec. Re.
30	8	1	A. M.	II	Oc. Dis.
	11	12	"	II	Ec. Re.
	6	51	P. M.	I*	Tr. In.
	7	1	"	I*	Sh. In.
	9	11	"	I*	Tr. Eg.
	9	20	"	I*	Sh. Eg.
31	3	57	"	I*	Oc. Dis.
	6	26	"	I*	Ec. Re.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

1896.

	d	h
Feb.	1	6
	3	18
	6	6
	8	17
	13	17
	18	17
	23	16
	28	16

ALGOL.

Feb.	3	7
	14	18
	17	15

ALGOL CONT.

1896.

	d	h
	20	12
	23	9

λ TAURI.

Feb.	18	13
	22	12
	26	11

R CANIS MAJ.

Feb.	1	10
	2	14
	8	6

R CAN. MAJ. CONT.

1896.

	d	h
	9	9
	10	13
	17	8
	18	11
	25	7
	26	10
	27	13

S CANCRI.

Feb.	15	10

δ LIBRÆ.

1896.

	d	h
Feb.	1	14
	8	13
	15	13
	22	13

U CORONÆ.

Feb.	12	17
	19	14
	26	12

U OPHIUCHI.

Feb.	11	15
	16	16
	21	16
	26	17

Continued from Hartwig's ephemeris in the *Vierteljahrsschrift*.

Marengo, Ill., 1895, Dec. 7.

J. A. PARKHURST.

Ephemeris of Short-Period Variables.

JANUARY, 1896.

[Greenwich Mean Time].

2279 T Monocerotis.

Max.	Min.
17.35	9.35

2509 ζ Geminorum.

Max.	Min.
5.90	0.80
16.06	10.96
26.21	21.11

4805 W Virginis.

Max.	Min.
12.79	4 59
30.06	21.86

6758 β Lyræ.

Min.
10.17
23.08

7149 S Sagittæ.

Max.	Min.
1.66	
10.04	6.64
18.42	15.02
28.81	23.41

7437 X Cygni.

Max.	Min.
7.68	0.88
24.07	17.27

7483 T Vulpeculæ.

Max.	Min.
3.05	1.75
7.49	6.19
11.92	10.62
16.36	15.06
20.79	19.49
25.23	23.93
29 67	28.37

8073 δ Cephei.

Max.	Min.
1.31	
6.68	5.07
12 04	10 43
17.41	15.80
22.78	21.17
28.14	26.53

Occultations Visible at Washington.

Date 1896.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle from N pt. °	EMERSION Washington M. T. h m	EMERSION Angle from N pt. °	Duration. h m
Jan. 2	8 Cancri	6.8	10 1	91	11 5	311	1 4
3	α Leonis	1.3	10 41	101	11 44	313	1 3
4	56 Leonis*	6.6	8 35	50	8 58	358	1 23
6	χ Virginis*	5.2	10 7	192	10 19	221	0 12
7	83 Virginis	6.0	17 20	173	18 14	259	0 54
19	21 Piscium*	5.8	10 10	9	10 44	297	0 34
23	B A.C. 920*	7.0	14 52	94	15 39	225	0 47
24	7 Tauri	6 0	5 41	16	6 37	291	0 56
24	18 Tauri	6.3	11 59	95	13 2	253	1 3
26	136 Tauri	5.3	16 20	93	17 9	284	0 49
28	κ Geminorum	3.7	9 40	158	10 29	234	0 49
30	ν Leonis	5 3	17 59	80	18 40	341	0 41
31	49 Leonis	6.0	7 23	87	8 12	322	0 49
31	38 Sextantis	7.8	14 57	106	16 2	333	1 5

* Below the horizon at Washington.

The angles are reckoned from the north point of the Moon's disc counter-clockwise. The times given are in Washington time. To reduce to Eastern Standard add 8 minutes or to Central Standard subtract 52 minutes.

The Variable Star Mira, *o* Ceti.—Mira is slowly increasing in brightness, and will evidently not reach maximum until some time in January. Two letters were upon our desk last month, calling attention to the tardiness of Mira's maximum last year, but were not read until the matter for the last number of Popular Astronomy was in type. These were by Mr. David Flanery, of Memphis, Tenn., and Mr. F. Bradbury, of Tarrytown. These indicate that the maximum of Mira will be more than a month later than the predicted time. Our visual observations give the following results for the magnitude of Mira: Oct. 16, 9.5; Oct. 29, 9.0; Nov. 11, 9.0; Nov. 23, 8.2; Dec. 2, 7.8; Dec. 7, 7.5; Dec. 14, 7.2. A photograph taken Dec. 2 with an exposure of 15 minutes makes Mira three

times as bright as the companion and about equal to the star *S* of Mr. Parkhurst's list in our last number page 166. The photographic magnitudes of the several stars vary considerably from the photometric magnitudes given by Mr. Parkhurst. H. C. W.

The Variable Star Mira.—In the *English Mechanic* of Nov. 29, Mr. Corder gives the minimum of Mira, 1895 Oct. 1, and the predicted minimum is 1895 Aug. 1-19, showing the minimum behind time 41 days. The predicted maximum was 1895 Jan. 13. My determination of that event was 1895 Feb. 23, showing 42 days behind time. There was then an orderly sequence in the ephemeris which is confirmatory of my observation. DAVID FLANERY.

The Variable Star Mira.—The published maxima for several years of o Ceti (Mira) have been wrong—have been in fact about two months ahead of the observed.

Last night I took a survey with a field glass of great illuminating power of what to the unaided eye seems a dark, starless part of the sky—found by prolonging a line drawn from α through δ Ceti to a point not quite as far distant from δ as the latter is from α. A still better way of finding Mira is to direct the glass to a point, forming with γ, ν and ξ Ceti and α Piscium, a long rectangular figure. In about three months from now—not as according to the published maximum—Dec. 9th, this dark spot will be occupied by a plainly visible star of probably 3rd or 4th magnitude. Last night, however, with the aid of the field glass, Mira could be seen—in fact I never entirely lose sight of her—as a very faint star of probably 9th or 10th magnitude. No indication of increase from the minimum were observed. But, in a few days, if I mistake not, the change will begin. In three or four weeks probably it may be seen with an opera glass, and possibly by the end of December the unaided eye will readily see that the dark space is no longer vacant. Thence on through January to about the middle of February it will continue to brighten on the deeply interested observer's gaze.

At this appearance there will still be time before twilight interferes to observe a part of its decline.

Mira to me is always of a beautiful rich red color, even when seen at the minimum with a small telescope. Her companion seems decidedly smaller or fainter.

F. BRADBURY.

The Variable Stars Mira and R Leonis.—In reference to the article on Mira there was one fluctuation which Mr. H. M. Parkhurst did not observe. I saw the star faintly at different times from the middle of December 1894 and between these times failed to find it. I kept watching it upon every opportunity and 1895, Jan. 12, found a very faint star which I was unable to say whether it was Mira or the *comes*. I was unable to do so because in Webbs Celestial Objects the *comes* on the authority of Burnham is given as 8.2 mag. But on the next night, Jan. 13, the day named for its maximum to my great amazement and some confusion Mira appeared as a 7th magnitude star or about that magnitude. I was very much disturbed in mind about this, doubting my own eyes and observations, for I had no expectation of any such fluctuations, indeed I had no expectation of any but looked for the star to rise gradually in light. But other fluctuations followed and to set my mind at rest, I ventured to write to Mr. H. M. Parkhurst enclosing a postal card and asked how he found Mira. Fortunately it was on his list and he very promptly and kindly replied, saying Mira. fluctuated greatly, also R Trianguli and R Leonis. This gave me courage, and

when some weeks later I wrote again in consequence of other fluctuations he confirmed my observations, giving me his photometric measure of 4.2, which very closely agreed with mine on same date. On this latter occasion he said that he had suspended observations on Mira as his comparison stars southwest of the variable were too low in the west. As I was using 66, 71, δ, γ, I kept on till Mira got too low in the city smoke and vapor. So then I was first and last at the work.

There was another star that acted unusually last year and the year before and is seemingly so doing the same this year. I mean R Leonis. This was the first variable which, under the stimulus of POPULAR ASTRONOMY, I undertook to observe carefully, and its history since then is briefly this. POPULAR ASTRONOMY gave maximum as due June 1:

Predicted Max.	1894, June 1	Found April 6	Max. May 10
" "	1895, Apr. 11	" Jan. 22	" Feb. 23
" "	1896, Feb. 20	" Nov. 16	" to Come.

The maximum of May 10th and that of Feb. 23 are mine and are confirmed in A. J. by Mr. H. M. Parkhurst, and they show a shortening of the period of about, not less than, 22 days. From this if the shortening is real, not transitory, the next maximum should be about Dec. 21st inst. and the star is moving up in brightness quite promisingly. It is a morning star but was definitely seen under nearly full Moon last week.

I have called the attention of *Knowledge* and publication was made of these observations. I wrote Mr. Yendell about it and he thinks Mr. Chandler will speak on the subject in due time.

There has been no chance, owing to the weather and the Moon combination, to observe the star for a week. It rises late these nights, too near the horizon for my power.

DAVID FLANERY.

Observed Maxima and Minima of Long Period Variables.

No.	Star.	Observations. Begin.	End. 1895.	No	Result. Phase	Date. 1895.	dag.	Observer.
103	T Androm.				Max.	Sept. 7.5	7.8	W. E. Sperra
"	"	1895 July 24	Oct. 23	16	Max.	Sept. 8.6	8.0	J. A. Parkhurrt
294	W. Cassiop.	1894 Dec. 5	Oct. 25	32	Max	July 11	8.6	"
678	U Persei	1895 Mar. 16	Oct. 19	18	Min.	July 25	11.6	"
1623	T Camelop.	1895 June 13	Sept. 20	11	Min.	July 30		W. Dearden
5070	Z Virginis	1895 May 17	Aug. 23	7	Max.	July 7		"
5190	R Camelop.	1895 May 25	Oct. 25	19	Max.	Aug. 11	8.4	"
5194	V Bootis			48	Min.	July 29	8.9	W. E. Sperra
5237	R "	1895 Aug. 7	Oct. 13	18	Max.	Sept. 22	7.5	"
6207	Z Ophiuchi	1895 Feb. 21	Nov. 26	22	Min.	Oct. 31	11.8	J. A. Parkhurst
6446	T Draconis	1894 Dec. 25	Oct. 22	34	Min.	Aug. 3	11.7	"
7085	RT Cygni	1895 May 9	Aug. 22	15	Max.	July 9	6.6	"
7220	S "	1895 June 13	Sept. 20	11	Max.	Aug. 4		W. Dearden
7458	V Delphini	1895 Feb. 21	Aug. 25	10	Max.	May ?		J. A. Parkhurst
2815	U Geminor			4	Max	Oct. 28	9.1	W. E. Sperra

NOTES.—

103 T Androm.	Other observed maxima are, Aug. 31.5, P. S. Yendell, Ast. Jour., XV, 173. Sept. 1, Walter J. Gill, Jr.
294 W Cass.	As far as known, the first visually observed maximum. A minimum of about 11.5 mag. probably occurred in Dec. 1894.
678 U Persei.	The period seems to be 314 days. M − m = 182 days.
1623 T Camelop.	The interval since Mr. Dearden's last minimum is 379 days.

Marengo, Ill., 1895, Dec. 7. J. A. PARKHURST.

Midday Meteor.—At 11:45 A. M., November 4th last, a young man by the name of J. Curtis Shuman of this place was so fortunate as to observe from a window, the flight of a bright meteor across the western sky. It appeared in the southwest about midway to the zenith and passing in a parabolic curve, disappeared near the northwestern horizon. It was of silvery color and left a trail.

W. E. SPERRA.

Jupiter Occulted by a Bright Meteor.—November 27 at 3:25 A. M., while observing in the vicinity of the great planet, a meteor of nearly equal brightness and of same color as Jupiter passed directly over him. It was of very rapid flight and made its aprearance about ten degrees nearly due south of the planet, and disappeared about the same distance north of it. The middle and brightest portion of its train was left exactly over Jupiter. W. E. SPERRA.

COMET NOTES.

Comet 1895 II (Swift), and Lexell's Comet.—In the *Astronomische Nachrichten* No. 3318, Dr. Schulhof gives new elliptic elements of Swift's comet discovered Aug. 20, based upon four normal places on the dates Aug. 25.0, Sept. 18.5, Sept. 27.5 and Oct. 22.5.

ELEMENTS OF COMET 1895 II.

Epoch Aug. 25.0, 1895 Paris mean time.

$$\left.\begin{array}{rl} M = & 0^\circ\ 34'\ 19''.2 \\ \pi = & 338\ \ 4\ 16\ .3 \\ \upsilon = & 170\ 18\ \ 7\ .8 \\ i = & 3\ \ 0\ 14\ \ 9 \end{array}\right\} 1895.0$$

$$\varphi = 40\ 39\ 30\ .5$$

$$\mu = 493''.743$$

$$\log a = 0.571004 \qquad \text{Period } 7.19 \text{ years.}$$

According to these elements the shortest distance of the comet from the orbit of Mars is less than 0.007 astronomical units in longitude 15°. It approaches the orbit of Jupiter at two points: in longitude 179°.5 at a distance 0.08 and in longitude 135° at 0.24. At about April 1, 1886, the comet was in the vicinity of Jupiter at a distance less than 0.4 and was subject to strong perturbations.

Dr. Schulhof calls attention to the similarity of the elements of this comet to one of the possible sets of elements calculated by Le Verrier for Lexells comet of 1770, after its encounter with the planet Jupiter 1779. Applying Tisserand's formula

$$nj = \frac{1}{a} + \frac{2\sqrt{\mathrm{A}j}}{\mathrm{R}^2 j} \cos i \sqrt{p}$$

he finds that the values of nj agree very closely for the two comets, more closely than for the comet 1889 V, which was for a time thought to be identical with

Lexell's, but the identity of which was disproved by the rigorous researches of Mr. C. L. Poor.

It is important that astronomers with powerful telescopes observe this comet as long as possible, for its next apparition in 1902 it will be under unfavorable circumstances. It is to be feared that the comet will not be seen again until 1931 hence it is necessary that the orbit be rigorously determined from this year's observation.

Our last observations of this comet at Northfield were obtained on the nights of December 6 and 7. It was then an extremely difficult object and we probably shall not be able to follow it longer.

Elements of Comet *c* 1895 (Perrine).—In the *Astronomical Journal*, No. 360, Rev. G. M. Searle gives the following elements of Perrine's comet, computed from observations at Mt. Hamilton Nov. 18, Northfield Nov. 22 and Georgetown Nov. 28:

$$\left.\begin{aligned} T &= \text{Dec. } 18.2470 \text{ Greenwich mean time.} \\ \omega &= 271^\circ\ 27'\ 6'' \\ \upsilon &= 319\ \ 38\ \ 51 \\ i &= 142\ \ 10\ \ 52 \end{aligned}\right\} 1895$$
$$\log q = 9.291725$$

These agree well with the rough elements given in Mr. Perrine's article (page 245) so that his conclusions as to the course of the comet, its unfavorable position after perihelion passage are correct. The following ephemeris by Mr. Searle will represent a little more accurately the comet's path and shows the rapid change in theoretical brightness, which reached a maximum on Dec. 17 of 70 times its brightness when discovered. The actual brightness was doubtless much greater and the comet must have been a conspicuous object in the southern hemisphere:

Ephemeris of Comet *c* 1895 (Perrine).

Date	α	δ	$\log \Delta$	Brightness
	h m	° ′		
Dec. 2	14 35.1	− 9 48	0.0268	5.7
4	14 47.4	− 12 20	9.9987	7.8
6	15 2.6	− 15 16	9.9701	11.2
8	15 21.7	− 18 37	9.9425	16.4
10	15 46.3	− 22 22	9.9182	24.8
12	16 17.8	− 26 13	9.9014	37.5
14	16 56.8	− 29 33	9.8981	54.4
16	17 39.9	− 31 24	9.9137	69.5
18	18 18.4	− 31 10	9.9479	65.9
20	18 45.4	− 29 20	9.9908	45.5
22	19 0.2	− 27 5	0.0318	26.9
24	19 9.3	− 24 56	0.0673	16.0
26	19 15.1	− 23 2	0.0974	10.0
28	19 19.0	− 21 22	0.1234	6.7

Perrine's Comet (*c* 1895).—This comet was first observed on the morning of November 26, and then on the three following mornings; bad weather prevented any more observations. On the first three mornings it presented essentially the same features; viz, a very bright head with nuclear condensation, and a spreading tail about a degree in length. But by the last morning (Nov. 29) a great change had taken place in the structure of the tail; instead of a simple tail, it was now divided in two, the two divisions making an angle of about 20°

with each other. 15′ from the head the division became complete. The southern division was straight and of uniform breadth, and could be traced for nearly two degrees from the head. The northern one was beautifully curved from the other, and was only about half as long. Thus two distinct types of tail were indicated. At all the observations the tail for a half degree from the head was very much brighter than the outer portion; this change of density was abrupt. At the last observation, the comet and tail could be easily seen with naked eye. Observed with 3-inch refractor.

Unfavorable weather and moonlight prevented any observations of Brook's comet (*d* 1895). WM. E. SPERRA.

Randolph, Ohio, December 11, 1895.

Comet *d* 1895 (Brooks).—This comet was a very swift moving comet and seems not to have been very generally observed. At Northfield we caught it on the mornings of Nov. 26 and 28. Bad weather and the lack of an accurate ephemeris prevented further observations until Dec. 17. The comet has moved rapidly north and is now among the circumpolar stars in Camelopardalis. It has diminished in brightness and is now rather difficult to pick up with a 5-inch telescope. Elements have been received by telegraph from Professor Leuschner of the University of California, who with his students, Messrs. Ferris and Ross computed them.

$T = 1895$ Oct. 21.2183 Greenwich mean time.
$\omega = 298° 59′$
$\upsilon = 83\ 1$
$i = 76\ 43$
$q = 0.84594$

More accurate elements are given in *Astronomische Nachrichten* No. 3320, just received, by Dr. H. Kreutz:

$T = 1895$ Oct. 20 887 Berlin mean time.
$\omega = 298° 13′.02$
$\upsilon = 83\ 9.22$ } 1895.0
$i = 75\ 22.79$
$\log q = 9.92362$

The following short ephemeris is from these elements:

		App. α h m s	App. δ ° ′	log r	log Δ	Brightness
Nov.	26	9 35 51	− 5 26.2	0.0312	9.5254	1.1
	30	9 16 47	+ 9 19.7	0.0490	9.4676	1.3
Dec.	4	8 49 48	+ 27 11.3	0.0669	9.4451	1.4
	8	8 11 2	+ 44 28.2	0.0845	9.4714	1.1
	12	7 16 42	+ 57 23.5	0.1019	9.5337	0.8
	16	6 8 2	+ 64 56.7	0.1190	9.6096	0.5
	20	4 57 4	+ 68 15.0	0.1357	9.6851	0.3

PRACTICAL SUGGESTIONS

129. Kindly explain the time given in POPULAR ASTRONOMY for the Minima of Variable Stars. For instance, the minimum of Algol for Dec. 16, is 13h. Does this mean sidereal time and consequently 1 o'clock in the afternoon? L. D.

Answer: Mr. Parkhurst and Mr. Yendell, in their ephemerides of variable stars, reckon the day as beginning at noon, in accordance with the practice of most astronomers. On this reckoning Dec. 16, 13^h is the same as Dec. 17, 1^h A. M., civil time.

There is a growing disposition on the part of astronomers to make the astronomical day coincident with the civil day, beginning at midnight, but this practice has not been adopted by any of the National Almanacs, and hence there is danger of confusion unless the awkward suffixes A. M. and P. M. are attached to the times given. H. C. W.

GENERAL NOTES.

We can assure our readers that forth-coming numbers of this publication will especially interest them both in variety and quality of matter.

Mr. P. S. Yendell of Dorchester, Mass., is doing us excellent service in computing his short-period ephemerides ahead of time for a whole year. We are also to have Mr. J. A. Parkhurst's valuable assistance in variable star study in the future as his health will permit.

Mr. Percival Lowell of Lowell Observatory, Boston, Mass., left for Europe, in the early part of December to be absent for a few months. American Astronomy will surely be advanced by his trip abroad. His parting remembrance to POPULAR ASTRONOMY was an excellent article which will appear next time.

Dr. Delisle Stewart who completed the post graduate course of study in Mathematics and Astronomy at Carleton College last June is now at work in the photographic department of Harvard College Observatory, Cambridge, Mass. He will be sent to the Arequipa station of Harvard College Observatory, in Peru, next February to assist in Observatory work there.

The Krakatoa Eruption.—*Knowledge* of last month has an instructive article concerning the Krakatoa eruption which occurred at the island of Krakatoa in the straits of Sunday, south of Sumatra during the last days of August, 1883. In 1884 the Council of the Royal Astronomical Society appointed a committee to collect and scientifically investigate, as far as possible, all data connected with the eruption. The report of that committee is the basis of the article referred to. The illustrations and the facts pertaining to the eruption are reliable and useful data.

Change of Axis Within the Earth.—Some very curious things get into print sometimes. A correspondent of the San Francisco *Examiner* from Tacoma recently says that beautiful shells, such as are found only in equatorial regions, have been discovered at Tacoma 400 feet under the surface of the tide flats, and that certain persons interested have been collecting data for a few years past bearing on the question whether or not the Earth's axis has changed in previous time, and that the finding of these shells settles the question affirmatively. How easy the conclusion!

The same article contains the startling announcement that probably in the fall of 1901, about Christmas time, when "the planets are all lined up in a row, on one side of the Sun (a thing not recorded astronomically)," another change in the Earth's axis will take place not to be repeated for more than a million of years in the future.

We do not doubt the finding of the shells in the artesian well, nor is it impossible that they belong to those known to exist only in the equatorial regions of the Earth; but because they are in that particular locality it is not proof that the axis of the Earth has changed through an angle of 30° or 40°, sometime in its past history, however interesting the incident may be. The incident comes infinitely short of that. Much less can anyone predict such results from any possible arrangement of the planets in 1901. The supposed arrangement of the planets at that date is an utter impossibility.

The Astronomische Gesellschaft Zone −13° 50′ to −18° 10′.—From a private letter from Professor A. N. Skinner, assistant astronomer at the U. S. Naval Observatory, we learn the observations for this zone are about completed. Mr. Skinner says: "I am just closing out a hard two years' work on the Gesellschaft Zone — 13° 50′ to — 18° 10′. There are nearly 9,000 stars in the zone and each star is observed at least twice. In the past two years I have made with the meridian circle between 20,000 and 25,000 observations. I usually work 4 hours on a stretch and when the stars are thick I have made 240 to 250 observations in the 4 hours. I have to hustle very lively to do it. It is only by thoroughly systemizing my work that I can do it. I have two very skillful assistants who alternate in helping me by recording, setting and reading microscopes. The eye-piece work I do myself. My assistant's names are Littell and King.

Measurements of Photographic Plates taken for the purpose of making an accurate catalogue of all the state in the heavens has decidedly gone beyond the preliminary stage. From the last number of the *Vierteljahrsschrift der Astronomischen Gesellschaft* we learn that during the year 1894 46 plates containing 11750 stars have been measured at the Potsdam Observatory. At Paris, where measurements have been going on for two years, the number of star-positions obtained is as follows, according to the reports of M. Tisserand, Director of the Paris Observatory.

In 1893, 27750 stars, from 72 plates.
In 1894, 32898 stars, from 120 plates. H. J.

Long Least Square Solutions by Professor Schur of Gottingen.—One of the most extensive least square solutions ever made has been recently published by Professor Schur of Göttingen. The heliometric triangulation of the stars in the cluster Præsepe gave rise to a series of 74 normal equations, involving 74 unknown quantities. The solution of this set of equations was effected by Professor Schur in ten weeks, by means of the usual Gaussian method of elimination. Professor Schur comes to the conclusion that no other method of elimination, such as the method by successive approximation, is to be compared to the Gaussian method, even though it might seem to promise a saving of labor in advance. Professor Schur mentions as the longest least square solution he has been able to find in astronomical literature a geodetic adjustment made by Baeyer, in which a set of normal equations with 86 unknowns was successfully solved by the famous computer Dase in three months. H. J.

Dr. See's Discovery of the Triple Star 70 Ophiuchi.—In *Astronomical Journal* 358, Dr. See announces the existance of a disturbing body in the system of 70 Ophiuchi. He says that the companion is rapidly departing from

Schur's Ephemeris, the angle now being out about five degrees, and he attributes this unexpected phenomenon to the action of an unseen body revolving round the companion in a period of about 40 years. This makes the visible companion move in an irregular curve, and violates the principle of constant areal velocity. The companion is distant from the centre of gravity of the new system about 0″.3, and moves in a retrograde direction. The announcement that 70 Ophiuchi is triple is certain to excite the most widespread enthusiasm both in this country and abroad, and when the details of the discovery are published we hope to present our readers with a full account of Dr. See's splendid achievement.

The Eclipse of the Moon.– On the 10th of March from the beginning of totality to the end of the eclipse, was observed at this station. We had been immersed in cloud at this altitude for several days and had little hope of viewing the phenomenon, but, contrary to expectation, just after second contact the sky suddenly cleared, and, followed by a crowd of guests who had come to the mountain to witness the event, I made my way from the hotel to the Observatory, but as some of these people had remained on Echo Mountain for a week awaiting a sight of this eclipse through the 16-inch telescope, I could not disappoint them, and, therefore, could myself spend very little time in studying the phenomena of the occasion. But several features on the disc interested me and two of these were a great surprise: one was the excessive brightness of Aristarchus which glowed with a brilliancy never before seen and which attracted the attention of every one, and in fact, projected its radiance to another neighboring crater, the other, was the appearance of a serpentine band, in width about twice as broad as the ring-mountain Tycho. It seemed to start from near the margin of the Moon in the northwest quadrant and passing centrally over it, preserving the same proportions, extended like a somewhat straightened or less crooked letter S, nearly to the line joining the northeast and east quadrant some distance from the Moon's limb. At first view I supposed it to be a long, narrow cloud, but its persistence showed that it was on the Moon. Its color was whitish and its boundaries fairly well defined. This may be a well known object but it was certainly new to me. I doubt if, without an eclipse, it ever can be seen.

Despairing of clear weather at this elevation, my son and an assistant packed the 4½ inch comet-seeker and its stand upon mules, and proceeded by bridle-road to Mt. Lowe, 6,000 feet above tide, emerging entirely above the clouds. He saw the same streak described above and has alluded to it in his report which will be sent later. LEWIS SWIFT.

Lowe Observatory.

The Colored Lunar Band.—Speaking of the eclipse phenomena mentioned in last paragraph a few days ago, Dr. Swift says:

Starting from near the Moon's center a luminous band extended as far to the east as Aristarchus, passing very near if not exactly over that crater, from near which it bent sharply to the east, somewhat like in form to a huge figure 7, the up and down portion of the character following the curved outline of the lunar limb though distant from it by estimation one-fourth of the Moon's radius. In its curvature to the north it passed, as at the March eclipse, centrally over Plato and ended a short distance beyond it to the west. The band was of a pale drab color and of nearly uniform width throughout its entire length, and on both occasions I compared its width with that of Tycho and found the two equal, so that it must have been fifty miles wide.

I wonder if any other astronomer has ever observed this curious ribbon-like band? LEWIS SWIFT.

Lowe Observatory, Echo Mt., Cal.
Nov. 19, 1895.

Remarkable Meteor.— An unusual number of bright shooting stars were noticed this morning radiating from a point near the zenith, or somewhat south of it. A very remarkable one made its appearance at $5^h\ 42^m$. I was placing the cap on the telescope, preparatory to closing the Observatory, when the Observatory became lit up as by a bright flash of lightning. I quickly turned to see the cause, but was only quick enough to see a most magnificent meteor as it was dying out. But what proved a most wonderful train was left. It was some less than five degrees in length and about three minutes in width, being brightest near the end where the meteor vanished. While I was gazing in wonder and admiration of it, it began to assume a serpentine shape and commenced folding and coiling itself up, not much unlike a snake. These gyrations did not cease until it had drawn itself up in a bunch, and appeared to the naked eye somewhat like a comet without a tail. At first it was nearly as bright as a first magnitude star, but all this time it had been gradually growing fainter until now it appeared as a faint fleecy cloud. It is to be regretted that the novelty of it was so great that it did not come in mind to turn the telescope on it, until it had passed in this stage, when it appeared in the 3-inch as all broken up in bunches and knots and tangles, and looked like a cloud of phosphorescence. The phenomena exhibited by the train lasted fully five minutes and vanished into nothingness at $9^h\ 18^m$, $+\ 63°$, near where the meteor vanished. The meteor's course was northwesterly. W. E. SPERRA.

Randolph, Ohio, December 13, 1895.

Comet Brook's *d* 1895.—Observations of the comet discovered by the writer on Nov. 21 have been made at this Observatory on every possible occasion. Work has been very much interfered with by clouds. Not until the sixth morning after discovery was I able to get a second sight of the comet. From the discovery position, R. A. $9^h\ 51^m\ 50^s$, $-\ 17°\ 40'$, and a position secured at the Lick Observatory Nov. 23, and kindly forwarded by telegraph to me from Harvard College Observatory by Professor E. C. Pickering, I made a computation of its approximate place on Nov. 27—my first succeeding clear morning—and had the comet at once in the field of the 10-inch equatorial. Its place at that time, Nov. 27th $15^h\ 40^m$ 75th meridian time, was, R. A. $9^h\ 29^m\ 30^s$; $+\ 0°\ 47'$. I found the comet considerably brighter and larger than at discovery.

The comet has had a remarkably rapid motion, and in a northerly direction, so that it has for some time been circumpolar, and evening observations have been secured. My latest observation was last evening, Dec. 16th 9 hours, R. A. $5^h\ 58^m\ 10^s$; $+\ 65°\ 30^m$. The comet is now becoming fainter, but was easily seen last night with the 10-inch refractor. The comet has been remarkably large, round, with ill defined edge, and, except on one or two occasions, very diffused central condensation. WILLIAM R. BROOKS.

Smith Observatory, Geneva, N. Y.,
Dec. 17, 1895.

The Total Eclipse of the Sun, Aug. 8th, 1896.—The Thomas Foreign Tourist company, of Philadelphia, are organizing a party of 200 to take a cruise to points of interest in northern Europe during the coming summer. Scientists

will be pleased to learn of an apparently excellent opportunity to visit a score of places of interest including a sight of the midnight Sun and total eclipse of the Sun, August 8th, 1896. Those interested should apply at once, for the party will be made up quickly. See advertisement.

The Growth and Magnitude of the Sidereal Heavens.—An article on the above topic is given elsewhere in this number. The editors do not hold themselves responsible for the views of the writer found on page 229 and following. They are insufficiently supported by facts of science to gain plausibility if they are not at variance with generally accepted proofs in moleclular physics. We have not space to be more explicit.

Curious Meteor Trail Seen at Grahamstown, 1895, Oct. 22, 0^h 5^m to 0^h 35^m.—The most extraordinary member of this class of phenomena was witnessed by myself and some friends shortly after midnight of Monday October 21 when a remarkably brilliant meteor darted from east to west across the sky, illuminating the whole heavens from zenith to horizon.

This lustrious illuminant was of a pear shape, a bright green color and about the breadth of Venus, while it possessed an apparent length equal to the lunar diameter but the wonderful sight of this visitor to our upper regions lay in the unique characteristics that developed in the long trail which remained stretched some thirty degrees across the southern heavens, a little west of the meridian and from which the meteorite seemed to detach itself when near α Grus, and after a further short flight to become suddenly extinguished. This phosphorescent wake was not the usual short-lived meteoric train of light of a few seconds existence only; but it took the unusual form of a floating tortuous band which continued to broaden out, lengthen and move in a gradually undulating figure for the interval of fully half an hour before it had entirely faded away.

In its first position this glowing trail streaked from Alpha Phoenicis, and passing over Beta Gruis, and a little north of Alpha Grus terminated a short distance to the west of this latter star. It early assumed a serpentine appearance with curious curves and crooks, and its upper portion, becoming greatly bowed, glided southward, with an advancing convexity; while the lower extremity moved with slower motion northward: so that before it had faded from view the upper or southern end had reached the bright Achernar, Alpha Eridani and streaming downwards with bended form crossed over the Magellanic Minor and thence moved with many a twist and twirl through the constellation Toucana, and along the confines of Indus and Grus, terminating at its northern extremity, in the vicinity of η and β Pisces Australis. This marvellous ribbon of light, on widening out, attained the width of rather more than one degree at its upper end, while it tapered off gently to three-fourths of a degree toward the opposite terminus and maintained throughout a maximum brilliancy in the part that passed beneath the constellation Grus which portion was also the last to fade from view. The outer borders were brighter than the interior of this uncommon sheen which shone throughout with a pale pinken lustre. Stars over which it passed did not appear to be dimmed by the interposition of its weird drapery.

This floating tenuous matter somewhat resembled the constituent of comet-

ary appendages, but its winding serpentine form could not be mistaken for one of those wanderers even though the observers had not witnessed its origin.

L. A. EDDIE.

Grahamtown, Cape Colony, S. Africa.
1895, Oct. 22.

Since forwarding to you last week my description of a curious meteor trail seen here on the 22d of October last, accounts have come to hand from various parts of the Colony that this phenomenon had been seen from several points, at some considerable distance from this city and from one another, viz: from Queenstown, about 200 miles north; Cradock, about 145 miles north by west; Graaf Reinet, about 275 northwest; Port Elizabeth, about 105 miles southwest, and at a railway station called Mineora siding. The descriptions given by the several witnesses from these stations, though brief, agree closely in the main points with my own observations; viz: as to the long duration of the trail, its "serpentine" form, "great length," "gauzy" nature, etc., and also to the great illuminating brilliancy of the meteor itself and its "green" color. L. A. EDDIE.

Grahamtown, November 4, 1895.

Erratum.—Please correct, as published in the October number of POPULAR ASTRONOMY, a typographical error in my report of the lunar eclipse of September last. Change the length of the versed sine from one-fiftieth to one-fifteenth of the Moon's diameter. LOUIS SWIFT.

BOOK NOTICE.

Molecules and the Molecular Theory is the title of a new book by A. D. Risteen and published by Ginn and Company, Boston.

As one thinks of it the fact is apparent that, in the multiplication of popular books on scientific subjects, the molecular theory has been strangely neglected. We do not know of any books available to American readers that pretend to give what is known of the constitution of matter in any complete and connected way. If a student wishes to know what has been done in this fruitful field of research, he must consult various sources of information, widely scattered and often difficult of access. Students of science in every department will be greatly gratified to learn of this small book of 223 pages which has been prepared to meet the demand for information in so important a theme.

The author begins with general considerations, and first states, in admirable way what the molecular theory is, noticing Dalton's contribution to it, which first occurred to him while he was studying carbon and hydrogen, and later his erroneous assumption of the similarity of molecules. He then speaks of Avogadro's and Ampère's suggestions that all gases when under the same conditions of temperature and pressure contain the same number of molecules per unit of volume, leading on to the meaning of molecules and atoms, and the distinction between them, how bodies are classified in regard to their molecular constitution and the possible mode of action of their molecular energies. The kenetic theory of gases involving the ideas of collision and free path, perfect elasticity and unequal velocity opens a field of thought and investigation that every scholar and teacher ought to know, at least in outline. There is some mathematics in connection with this and other topics that popular readers will not easily read, but that should not hinder the perusal of the book, for the results are what is wanted for the general scholar with some idea of the methods by which they are obtained.

The same may be said in regard to the other divisions of the book pertaining to the molecular theory of liquids, the molecular theory of solids, molecular magnitudes and the constitution of molecules. The range of thought is wide, the expression easy and concise and the illustration both by figure and example very clear and helpful to the popular reader. The author has done good service in presenting a difficult theme in a masterful manner.